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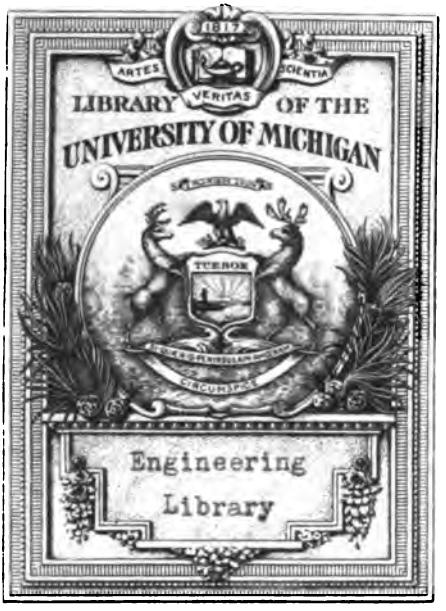
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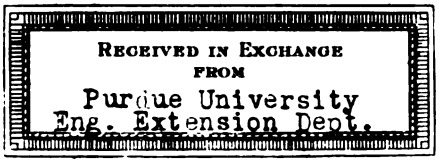
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VOL. VI OCTOBER 1922 NO. 2

Fundamentals of Construction and Maintenance of Secondary Type Highways

By
CHARLES C. ALBRIGHT

BULLETIN NO. 1
ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

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BULLETIN NO. 2
ENGINEERING EXTENSION SERVICE

House Construction That Reduces Heating Costs

BY
JAMES D. HOFFMAN
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PURDUE UNIVERSITY
LAFAYETTE, INDIANA
MARCH, 1923

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HOUSE CONSTRUCTION THAT REDUCES HEATING COSTS

Buildings of the larger type, especially those relating to community needs, have been carefully studied by the architect and the engineer and excellent standards of construction have been developed. The office building, the school, the auditorium, the factory and the apartment building, in their individual fields and according to their respective needs have all commanded the best in science and skill which the country affords, with the result that they have become models of convenience and economy. Residence buildings, on the other hand, especially those costing under seven or eight thousand dollars, principally because of the smaller investment but partly because of the urgency of the call elsewhere, have had less attention and so, in a sense, have been neglected by the engineer and the architect and turned over to the best judgment of the owner and the builder. As a result, the houses we live in need our serious consideration.

The residence problem throughout the country has become acute and there must be, in the near future, a strong revival of small building projects to satisfy the unprecedented demand now existing for new houses. With this prospect in view it is fitting to discuss the most outstanding imperfections in our present practice and suggest some changes for the better. This is a large field to enter and no attempt will be made to cover it. Only one type of construction will be considered, the framed-wall type sometimes called the balloon-frame construction. This type of construction has many possibilities for good or ill, since it may be either the best or the worst for the comfort of the occupants, according to the care with which it is planned and constructed.

A survey of the residence situation in any part of the country will show a large preponderance of this framed-wall type of housing, in fact, most American residences are so constructed. Because of the predominance of this type of house in the economy of the home life of the country we should pay particular attention to its development along right lines. This pamphlet, therefore, is intended to set forth some of the present weaknesses in the framed-wall type of construction and to suggest reasonable modifications which may be recommended as substitutes for present building practice. It is the hope of the author that all persons who contemplate building may read these suggestions and be benefited by them.

Points to Be Considered in Residence Building

In building residences four things should be kept in mind—the convenience of the occupants, the efficiency of the building, considering it as a physical plant, the artistic effect of the finished structure and the first cost. Of these, the average builder takes account of the convenience, the artistic effect and the first cost, but seldom considers efficiencies.

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Structures, even as machines, have efficiencies. These relate to certain physical values, such as the durability of the materials, the quality of the workmanship, the annual expenditures for upkeep and the annual expenditure for heating, all of which are factors in the formula for efficiency. Of all these factors, the annual expenditure for heating is the one most frequently overlooked in connection with the character of the building itself. In new building projects, of course, heating systems are carefully considered, but always as one system compares with another system and not from the standpoint of how the (any) system of heating may be influenced by the type of building which surrounds it.

Heating systems vary in efficiencies, that is to say, one heating system may, under like conditions of service, heat a house throughout the heating season with a less expenditure for fuel, than would be possible with another system, but, vary as these efficiencies may, the gain or loss is but a small amount when compared with that gained or lost from good or bad house construction. There is no desire in this discussion to under-emphasize the care necessary in the selection of the type of heating system to be installed, but rather to put greater emphasis than ever before upon the house which surrounds it.

Improvements Would Save Fuel Bills

Annual fuel bills should be seriously investigated. In the year 1920, according to the Indiana Public Service Commission, approximately $54,000,000 were spent by the people of the State of Indiana for domestic fuel. At a very modest figure 10% of this could have been saved if the people of the state had been more careful in the operation of their residence heating apparatus. This saving, $5,400,000 is no mean sum and is within the reach of the people of the state if they will only become thoroughly familiar with their heating systems and acquire the art of firing. That one may grasp the full significance of what this amount of money saved would mean to the state of Indiana, an investigation was made of the costs involved in operating the twelve or thirteen institutions of higher education within the state, for the year mentioned, and the $5,400,000 more than equaled the entire expenditure of all these institutions.

The preceding paragraph refers only to the operation of the present heating plants as they now stand in the residences of the state. Now what would happen if the houses themselves were improved? It is only too evident to those who have made a study of the present practice of house building that the present construction is very bad. No matter whether this is due to ignorance, indifference or to willful evasion, the average house is bristling with hidden defects which, if attended to at the proper time, could be eliminated with small additional expense. Having in mind only those reasonable improvements which should be

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made in every case, the yearly fuel bills in the average house might be reduced, because of house construction alone, fully 25%. That is to say, that whereas the annual soft coal fuel consumption in heating the average residence is now understood to be about one ton more than the total number of rooms and principal halls in the house, with a type of construction that is not only possible, but which should be expected in every case, this amount of fuel should be reduced to, at most, three-quarters of a ton for each room and principal hall in the house. As an illustration—if the average fuel consumption for heating a cottage of six rooms, bath and hall, is now about nine tons of good soft coal for the heating year, with improved construction this should be about six tons. With coal at $10.00 per ton and interest at 6%, this saving of $30.00, in one year, would cover a possible increased expenditure of $500.00 on the house. If we could change our building construction that the savings mentioned would be possible, the state of Indiana, alone, would profit annually by about $13,500,000. This is very nearly the full amount asked of the state legislature this year for the entire state budget for the bi-ennium. Of course, no sudden change can be expected in this regard. Present buildings can be but little improved, but it is hoped that for all new buildings suggestions for better construction will be seriously considered.

How Much of the Heat of the Fuel Is Saved?

In these times of high prices and of fuel conservation it is only natural that the householder should be inquisitive as to what percentage of his invested fuel bill really goes to the purpose for which it was intended. A pound of soft coal (most residence fuel in this part of the country is soft coal), selected from various mines in the country, may contain anywhere from 10,000 to 14,500 heat units. Of this amount, when the coal is burned in the average heating system, at least 40% is lost through imperfect combustion, by radiation and by convection up the chimney. Much of this 40% loss cannot be avoided. The rest, say 60%, finds its way into the living interiors of the building. It is this 60% we are now especially concerned with.

If our houses were built with insulated sides like fireless cookers, we could make them comfortable throughout the average winter with the use of but a small amount of fuel. This construction would not be desirable from the standpoint of health, because we need fresh air, but our present practice is quite the opposite. Because of imperfect construction we are not able to close up the average house on a winter's day tightly enough so that it can be made comfortable at all. This is especially true when there is a high wind. As a consequence, most of the 60% immediately goes through the walls, ceilings and floors to the outside air and is of little usefulness in maintaining warm room interiors.

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The Framed Wall

As previously stated, this may be the best type of insulated wall or the worst, depending upon the design and the care with which it is constructed. Fig. 1 shows a horizontal section of such a wall as it is usually laid out. It will be noticed that the studs are set 16 inches on centers with the outside and inside finish nailed directly upon them, leaving an inclosed air space, approximately $3\frac{3}{4}$x$14\frac{1}{4}$ inches. It is this air space which may be a friend or any enemy, as we choose. The temper-

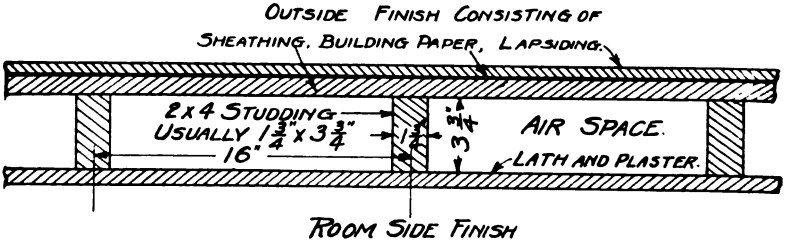


Fig. 1

ature of the room air is supposed to be maintained at 70° and the temperature of the air space is somewhere between this and that of the outside air. If the outside finish is tight the space temperature is maintained more nearly to that of the inside air, on the contrary if the outside finish is loose and open, the space temperature is low and there is more heat lost through the inner lath and plaster finish to this space.

The one-half inch of lath and plaster finish next the room is one of the serious weak points in this type of wall, as heat and air easily pass through it. As a convincing illustration that plaster is a very poor insulator, one has but to glance at almost any second-floor plaster ceiling where the upper side of the joists are not covered by a tight floor. Such ceilings show parallel dark and light lines alternating with each other. The dark lines are the spaces between the laths that have become filled with the dust particles separated from the air in its passage through to the attic space. That part filled by the laths offers more restriction to air passage and shows lighter in color. Our present practice on interior wall finish leaves much room for improvement.

Some progress has been made in the development of a composition wall finish. One form has a paper base and a plaster face, the plaster being held to the paper by woven wire or other form of binder. Another form has a plaster center reenforced with wood fibre and both surfaces covered with heavy paper. Paper is a good insulator and is very effective in cutting off air transmission. It would seem, therefore, that some such solution may eventually be worked out and that an effective interior wall

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surfacing, at a price approximating that of the present type of construction, may become generally used.

A modification of the present interior lath and plaster construction, that can be highly recommended, is shown in Fig. 2 (*a*) and (*b*). The first shows building paper nailed to the inner face of the studs, with enough slack between the studs to permit the plaster to clinch on the inside of the laths without tearing the paper. The laths are then put on in the usual way and the surface plastered. Care should be exercised in so running the paper that it is satisfactorily lapped and that the slack is uniform on all overlapping edges. When laying the paper, the

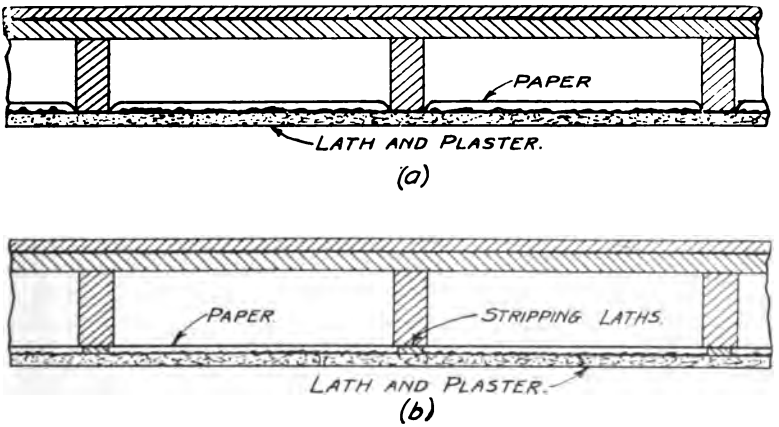


Fig. 2

upper sheets should be put on first so as to permit the successive lower layers to overlap the ones above. This will retard the passage of air through the joints from the room to the stud space. Paper put on in this way will have a tendency to cut off air circulation and produce a dead air space between the paper and the plaster. A more satisfactory way of laying the paper is to stretch it tightly over the studs and strip the inner face of the studs with laths. The laths for the plaster wall are then nailed to these stripping laths, as shown in (*b*) of the same figure. If this method is used, it will probably be necessary to build up the thickness of the window and door casings by the thickness of the stripping laths, on account of the increased thickness of the wall. When applied to a ceiling this objection does not hold. Either of these two schemes, if properly applied, will cause a marked saving in fuel.

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As there is a considerable loss of heat from the room to the stud spaces, it becomes important to make these spaces as tight as possible to avoid the escape of heat to the outer air. Many buildings are constructed with the stud spaces opening up directly into either the basement or the attic spaces, or into both as shown by Fig. 3. Such construction is bad in the extreme. All stud spaces should be tightly closed at both basement and attic floor lines, otherwise these become circulating air spaces and act as chimneys to carry the heat to the attic. Any good method of blocking off at these points may be recommended. In old buildings where the studs extend to the plate, Fig. 3, at X and the floor meets the inside edge of the studs, this space is probably open. The only way to correct this is to insert *filler-blocks* between the studs on a plane with the floor, as shown in Fig. 4. Where the house is new construction, a number of methods may be resorted to, the most satisfactory of which is to floor over the entire first floor area as far as the sheathing on all sides, Fig. 5, and set the studs upon plates laid broadside upon the top of this floor. This arrangement will effectually cut off all air communication between the basement and the stud spaces.

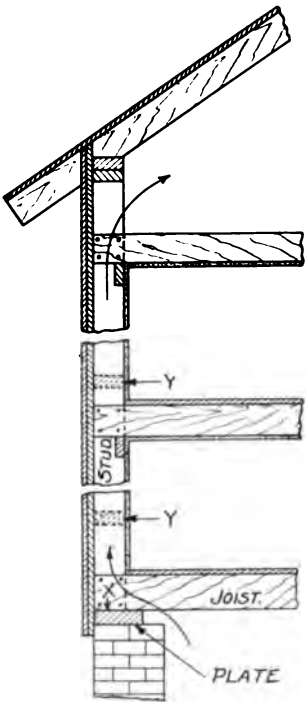


Fig. 3

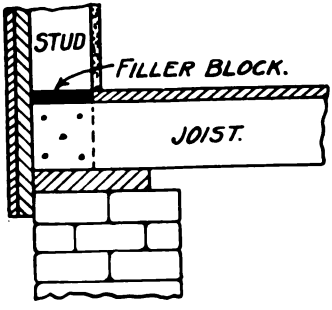


Fig. 4

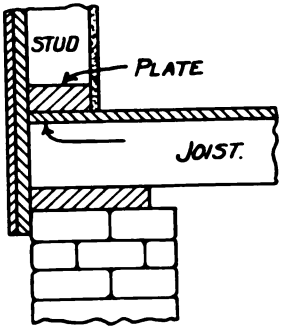


Fig. 5

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At the attic floor line, where the joists are laid upon the rafter plates, there is no difficulty because the inside finish of the upper rooms extends up to and includes the plates, Fig. 6, at A. On the other hand, in attics where head-room is at a premium, for storage purposes, the roof line is usually raised some distance above the floor line and the floor joists are supported upon ribbon boards let into the studs. In such cases the stud spaces are usually wide open to the attic, as shown in Fig. 3.

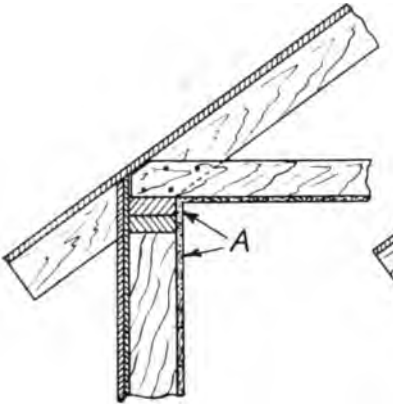


Fig. 6

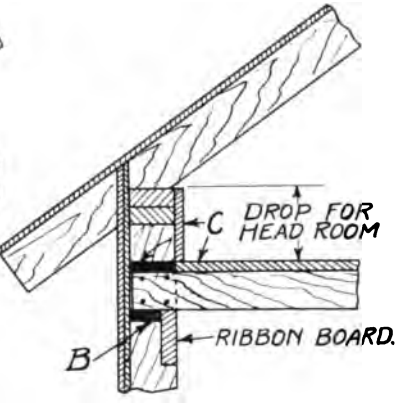


Fig. 7

These may be closed as shown in Fig. 7. As far as the spaces are concerned, these can be effectually closed by stripping the under side of the joists behind the ribbon board, as at B, but a better way is to floor the attic tightly and fill in between the studs or sheathe the studs up to the plates, as at C. This cuts off not only the stud spaces but it reduces the heat losses through the upper ceilings to a minimum, as stated later in this discussion. If this sheathing is continued far enough to fill in between the rafters, it will keep out the dust and soot particles which otherwise enter at the eaves.

In addition to what has been said about closing the extreme ends of the stud spaces, it is highly desirable to break these up into smaller spaces by nailing-in stud-ends sawed to fit between the studs, as shown dotted in Fig. 3, at Y. Such blocks are called *fire-blocks* and not only improve the insulating qualities of the wall but they reduce the fire hazard and are recommended by fire insurance companies. Fire from the basement frequently breaks through the first floor and passes up between the first floor studs of an interior wall, then between the second floor joists to the outside wall. In such cases fire-blocks immediately above the level of the second floor are very effective in checking the fire.

With the stud spaces effectually closed and sealed, next investigate the outside finish. The usual construction here is, one

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layer of 7/8-inch sheathing boards on the studs, one layer of building paper on the sheathing and lap-siding on the paper. This is a good arrangement providing good materials are used and care is exercised in its construction. This finish should be not only a good heat insulator but it should be tight against air leakage. Several critical points in this construction should be mentioned. Lap-siding, so generally used in this type of construction, is sel-



Fig. 8

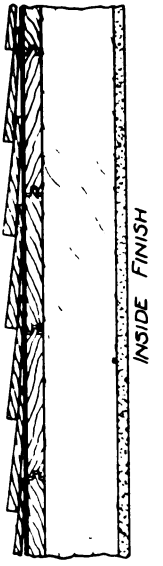


Fig. 9

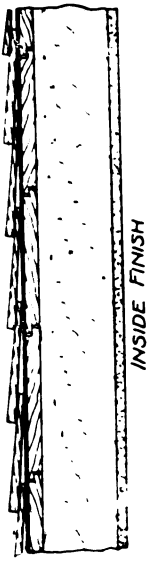


Fig. 10

dom tight. It therefore rests with the building paper and the sheathing to be the protecting elements. Fig. 8 is a type of construction that is very bad. The building paper here is omitted and the sheathing boards are butted on the edges. In this case the rooms on the windward side of the house could scarcely be comfortable no matter what heating system were put in, because of the effect of the wind leaking into the stud spaces. *Building paper or equivalent should always be put on over the sheathing.*

Sheathing boards should be straight and should be free from loose knots, and the edges of these boards should have either a tongue-and-groove or a half-lap joint. With such edging, shrinkage may take place without opening the joint for air passage. A butt joint may be comparatively tight when first put in, but will not remain so. After the boards have been nailed to place, shrinkage cracks of considerable size open up. A good layer of building paper may cover such cracks and cut off a large amount of air leakage, but there will still be a large heat loss because of the openings through the sheathing. Figs. 9 and 10

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show the two joints recommended. From a practical standpoint one is about as good as the other. The ship-lap, Fig. 10, is somewhat cheaper in first cost and is easier to lay, consequently it is the most frequently used but the style of the joint permits more freedom for warpage.

No less important factor in the construction of a well insulated wall is the workmanship. Having supplied first-class materials for the job the owner has a right to expect first-class workmanship, but unfortunately this is not always the case. A careless workman will probably build a substantially strong wall, but the tightness of the wall and the elimination of cracks give him little concern. Many houses are erected on rush contracts for immediate sale, or by owners who are not informed as to what is good or bad practice and in such cases defective work is quite common in concealed places. These defects cause unnecessary heat losses which in extreme cases may become as great as three times the loss expected from a well constructed wall. Heat loss calculations, for estimating the size of the heating system, always contain three terms, exposed wall surface in square feet, exposed glass surface in square feet and room volume in cubic feet. In rooms having large exterior wall surface, such as corner rooms, the heat loss from the walls becomes one of the principal factors to be considered.

Windows

The window problem in the modern residence is an important one. The value of light room interiors is being increasingly recognized and more windows in outside walls are demanded. Since the heat lost through one square foot of glass window is about four times that through a square foot of the average framed wall, the heat loss due to conductivity is something to be considered even though no mention is made of the tightness of the fit in the casement. Add to this loss the heat loss due to air leakage and the problem becomes increasingly important.

Buildings are subjected to air inleakage through the walls, floors and ceilings, and around the windows and doors. Of these, that through the openings around the windows and doors is probably the least considered. Because of the large number of windows in the modern residence, those fitted loosely in the casings (this includes a large majority) become a very important factor in the heating economy of the building. Considerable experimentation has been carried on to determine just how much the heating of the building is affected by loose windows, but as yet the results obtained are open to so much guess work that it is not safe to give anything but the most approximate estimates. The following conclusions have been arrived at by Mr. H. G. Whitten after a long series of experiments, and these may be taken as a fair statement of the case:

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1. "Average wind velocity in localities where heating is important, miles per hour, 13.
2. "Average sash clearance, inches, 1/16.
3. "Air pressure equal to a 15-mile wind, against a window having a 1/16-inch clearance, will force 146 to 185 cubic feet of air through each lineal foot of window clearance per hour.
4. "Insulated windows, metal weather strips, etc., reduce the leakage as low as 1/5 to 1/9 of that found in the average window."

When it is realized that many windows have larger clearances than 1/16-inch, and that it takes much good heat from the coal to raise the temperature of this inleakage from zero outside to 70° inside, the importance of the loose window problem will be better appreciated.

In the northern parts of the country, where people expect to build to resist the cold winters, the problem is met by putting in double windows (two-glass in the same sash with a thin air space between), by insulating the ordinary window sash with metal weather strips or other equivalents, or by putting on temporary storm windows. As a result, it is reported upon good authority that it takes less fuel per year for the same room space for houses in the northern part of the United States and in Canada than it does for houses in the southern part of the United States (specifically mentioned, Texas). This seems to bear out the belief common among heating engineers, that the wind effects upon heating efficiencies are more serious than extreme still cold.

As an illustration of what is happening in very many homes of the country on any zero day, assume the following: A living room 13x15x10 feet, with a total window perimeter of 50 feet, a crack of 1/16-inch around each window and a 15-mile wind striking the windows. Using the lower value previously quoted, 146, there will be 7,300 cubic feet of outside air entering the room per hour around the windows. That is to say, 3.75 room volumes of air must be heated from zero to 70° every hour at an expenditure of 9,290 BTU. With soft coal at $10.00 per ton and 12,000 BTU. per pound, and with 60% of this credited to the house, there will be an expenditure of 15.5 cents per zero day of 24 hours solely for heating the window inleakage in this one room. Some of this expenditure should not be charged up as loss, because no matter how hard constructors exert themselves to make a well

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insulated job, there will still be some inleakage. It is also desirable that a certain amount of outside air enter the houses to insure healthful room conditions. Ventilation, however, may be accomplished in a better way by the opening of windows or through specially prepared ventilating ducts.

To prove the effectiveness of any heating system, it should be tested on a windy day. High winds prove a serious handicap to satisfactory heating. This is especially true when furnace systems are employed to do the heating. With a heavy inleakage, the air pressure within the rooms on the windward side is sufficiently great to overbalance the upward impulse of the warm air from the furnace to the rooms and there is a reduction (at times a complete reversal) of the warm air current, resulting in a lowering of the temperature of the room air. Since most of the framed residences are heated by furnace heating systems, the factor of inleakage is a very important item. Window insulation is now frequently used and will continue so increasingly.

Storm windows have just been mentioned as one means of reducing excessive inleakage. These can be especially recommended for windows on the sides of the house which get the heavy winds, usually the west and north for this locality. Storm windows usually have a frame thickness of 1-inch to 1 1/8-inch to fit within the outer recess of the window casements. The frames may be fixed or swinging. Windows not to be used for ventilating purposes would be fixed, since this is the simplest method, others may swing, preferably from top fastenings, because this permits free circulation of air without opening for rain or snow. Ordinary sized windows may conform to the glass divisions of the under window but large windows, especially those that swing, should have sufficient partitions to give them rigidity. Single strength glass is usually used to give lightness. It is the author's opinion, from personal experience, that storm windows should pay for themselves, in coal saved, in two to three years' service.

The Attic Floor

Most of the attics in residences are not floored. This is a serious mistake even though the attic is not to be used for living or storage purposes. Heat losses are continuous throughout the heating season of eight months and at no place within the house is this loss more noticeable than through the upper ceiling. For the purpose of illustration, suppose the average house has an attic floor area, exclusive of that covering closets, of 600 square feet. Will it be an economy to floor this attic?

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Cost of flooring attic: Allowing 75 square feet of floor surface for closets, 675 square feet of floor area may be covered tightly with 6-inch No. 2 flooring at the present price of lumber, for $48.45 ($36.45 lumber, $12.00 laying). This is a first cost expense and will not be duplicated. There is, however, a loss of interest to the owner on that amount of money at 6%, amounting to $2.90 per year.

Attic Not Floored: In the average framed house, when the outside temperature is zero, the temperature within the attic may be expected to be 25° to 30° above zero. With the normal room temperature 70°, the heat loss through one square foot of plaster ceiling under such conditions will probably approximate 40 heat units (BTU.) per hour. For 600 square feet this will be 40x24x 600 equals 576,000 BTU. per day. The average heating day in this locality for the heating season is about 44% as severe as a zero day, hence for an average day the heat loss to the attic from these second floor rooms will be about 253,440 BTU., and for the average heating year of 240 days the loss will be 60,825,600 BTU.

Attic Floored: If this same house were floored, as stated above, the heat loss through the ceiling and floor would be about 40% of that just figured for the ceiling alone, consequently, the heat saved in one year by flooring the attic is .60x60,825,600 equals 36,495,360 BTU. With a grade of soft coal averaging 12,000 BTU. per pound and 60% of this credited to the house, this would amount to 2.53 tons of coal in the bin, and with this coal selling at $10.00 per ton, would mean a financial outlay per year of $25.30. At this rate the coal saving would pay for the floor and the interest on the money invested in the floor, in approximately two years.

Fuel saving, as mentioned above, however, is not all there is to the problem. The extra heat lost from the rooms through the ceiling would necessitate the installation of 600x40x.60÷ 250 equals 58 square feet of steam radiation. This, with its proportional share of pipes and fittings, would cost at least $43.00, which in itself almost pays for the floor. If a hot water system is installed the extra cost will be about $65.00. If a furnace system of heating is used, the amount of additional cost would not be so striking, but it is safe to say that it would be worth considering.

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The Bungalow Type

We have so far been talking of general points that affect all houses having framed walls. Now let us look at a more specific case, the Bungalow. Whatever has been said in the above may apply with equal force to all houses having framed walls, either wholly or in part, including the stucco or brick veneer, but one point should be strongly emphasized in connection with the bun-

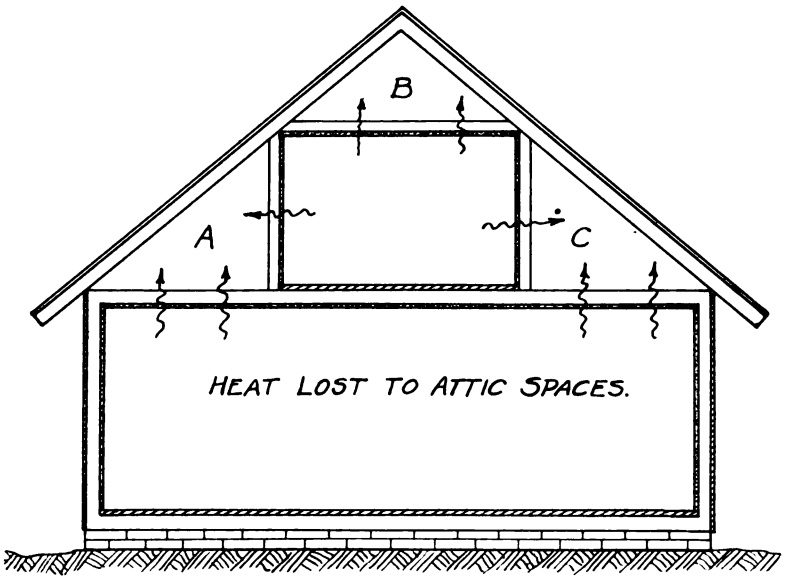


Fig. 11

galow, and that is the tremendous heat losses so often permitted to go to the attic spaces. These houses are too frequently hard to heat and an analysis of the causes almost universally shows the attic spaces having little or no insulation on the attic side. See Fig. 11, A, B and C.

It is a very common practice, when planning bungalow houses, to have one or more rooms on the second floor. These rooms may or may not be in immediate use and may not be furnished, but this fact does not remove the trouble because heat losses continue. Not only are the floors omitted from the attic spaces but the side walls of the second floor rooms, exposed to the attic, are seldom sheathed. This makes a condition more exaggerated still than the attic floor problem previously illustrated. One case like this, a little more striking than usual but

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illustrating the point, was of a bungalow having better than average material and workmanship and having a furnace heating system that, according to the most careful calculations, had excess capacity but which failed to hold the room temperatures on a zero day to within 20° of the guarantee. The house in this case had a heavy 18-inch stone wall to the eaves of the roof, consequently the trouble was above this horizontal plane. The house was of massive construction and no weakness was visible to the casual observer. There seemed to be no reason why such a heating system in such a house should not give satisfaction, until an examination of the attic revealed the fact that there was only one 8-inch board (footboard) over the joists in each space, A and C, no flooring in B and no sheathing of any kind on the room studs next these spaces. Above some of the first floor rooms, therefore, there was only the customary ceiling of ½-inch lath and plaster and these rooms were depleted of their heat through the ceilings. The second floor rooms were giving up heat through both the side walls and the ceilings. Standing at the foot of the ornamental stairway, one could feel a cold draft of air coming down from the second floor rooms although these rooms were supposed to be amply supplied with heat. The heating system was supposed to be faulty and had been frequently examined to determine the cause of the trouble. No one suspected that the house itself was the offender.

In the case in question, the reason for the omission of this small amount of flooring and sheathing was not because of the first cost, but it was because of the lack of information concerning the subject on the part of both the owner and the builder. An expenditure of $50.00 in No. 2 flooring and Beaver Board or plaster board, for the floors and the walls respectively, would have solved the discomforts of two years and saved many dollars in fuel bills.

As a corollary to the heat loss proposition, any construction that keeps the heat in on a winter's day will also keep the heat out on a summer's day. This is not exactly along the line of fuel saving, but as an additional argument favoring tight house construction, it may be said that the peace of mind of the occupants in the summer time will in most cases be enhanced by such construction. A striking case illustrating this was in a two-story frame house, having a third story attic room, as shown by Fig. 11. This room had a warm air heat supply entering through a floor register located in the middle of the room, which

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should have supplied the room with ample heat for any winter weather, and it had a ventilating stack from the ceiling of the room through the roof with regulating damper. This room, however, was uninhabitable in the winter because it was too cold and likewise in the summer because it was too hot. Upon recommendation, the room studs on the attic side were sheathed and the space B was floored, at an expense of $50.00, and not only were the winter troubles entirely overcome but the room proved to be quite satisfactory in the summer time.

Chimneys

Another source of annoyance and waste in the operation of small residence plants is the unsatisfactory operation of the heating plants, due to unsuitable chimneys. In chimney operation, height produces draft and net cross-sectional area gives capacity. That is to say, the higher the chimney the greater the "pull" on the chimney gases and the less the danger of smoking at the furnace. Also, the larger the net area of the chimney the more coal may be burned in a given time without choking the chimney enough to kill the draft. These two factors, height and area, are inter-dependent and each should be considered with the other. In this connection some general facts should be observed.

Chimney Height: The least height of a chimney for residences is variously stated from 30 to 35 feet. Chimneys less than 30 feet are likely to be erratic in their action. One would not be safe in saying that no chimney less than 30 feet should be built, because many bungalow type houses and other one- to one-and-one-half-story houses have chimneys less than this amount. It is correct, however, to say that if the owner wishes at all times to have a good draft during any weather conditions that may prevail, a chimney less than 30 feet in height should not be put in. The furnace codes approved by the various engineering societies interested in furnace heating, give as a least value, 26 feet above the furnace grate, which, to say the least, should be considered a minimum in all cases.

Cross-Sectional Area: In the average residence the cross-sectional area more frequently causes trouble than the height. The ideal section for any air duct is a round one. This does not work in very well with the brickwork, however, and a square section should be approached as nearly as possible, keeping in mind that whatever shape is adopted it must fit the usual sizes of

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bricks. In many chimneys already built the section is a long, narrow one, the least dimension being the width of one brick (4½ inches). This is entirely too small to give good service. Because of the mortar burr projecting from the joints between the bricks, this dimension is frequently as small as 4 inches. There is a dead zone next to every frictional surface (that next to an ordinary brick wall is extravagantly large) which is ineffective as free area. The gases moving along such a surface do not slide but roll and tumble, thus farther restricting the free passage up the chimney. In a chimney as stated, having a thin rough flue, this neutral zone may be sufficient to practically nullify the entire draft area. One prominent authority states that this zone extends a distance of two inches or more from each brick surface toward the centre of the chimney. From a practical standpoint, therefore, a nominal 4-inch by 12-inch standard chimney flue is very much less effective than an 8-inch by 6-inch flue, if such could be constructed. In practice, no chimney flue should be made of less internal area than an 8-inch round or an 8-inch by 8-inch, and in moderate sized houses the working conditions of the chimney are improved if this is enlarged to an 8-inch by 12-inch.

Chimney Lining: All chimneys should be lined with the best hard burned flue tile lining throughout the entire length of the chimney, the tile to be not less than ¾-inch thickness. This is especially necessary if the chimney is built of a single thickness of brickwork or of a cement block construction. There are two reasons for this. The smooth interior of the tiles eliminates a large amount of the friction usually found between the moving column of gases and the inner surface of the brickwork, and in addition, tiles are a safeguard against fire, since they cover up any open joints or cracks often occurring in the average mortar joint in one-brick walls. An examination of many attic chimneys will reveal such cracks. They are easily distinguished by a feather of black soot and dust around the opening. In normal operation, the draft within the chimney is sufficient to cause the surrounding air (say attic air, because most of the roof fires begin in the attic), to pull inward toward the chimney. When a heavy deposit of soot collects upon the inner surface of the chimney and this is fired by an extra hot fire in the furnace, the gases trying to escape from the top of the chimney are so great that the "pull" of the chimney is overcome and a reverse condition takes place. The pressure within the chimney now is greater than that of the air without and the hot gases are forced out

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through the cracks to the attic, igniting any combustible material in their path. Many of our mysterious roof blazes could probably be traced to this one defect in chimney construction. Tile linings effectually cut off gas leakages to the house, but emphasis should be laid upon the fact that the lining should be of the best and strongest quality, each section end should be well bedded in a good mortar joint and the entire lining should be laid against the brickwork but should not be slushed-in. This will permit the lining to expand and contract free from the chimney proper, thus avoiding the cracking and crumbling of the lining.

Interior vs. Exterior Chimneys: Convection of air or gases (their tendency to rise and mix) is due primarily to heat. Any body of gas upon being heated expands and becomes lighter. Since all gases are, comparatively speaking, perfectly fluid, the lighter (warmer) volumes rise and the cooler and heavier volumes fall, an interchange due to gravity. It can easily be seen, therefore, that a protected chimney that keeps the gases from losing their heat as they pass up the chimney will produce a better draft than one which is not well protected and permits the gases to lose their heat. That is to say, an interior chimney (one running up through the house, inside the outside walls) will give more uniform draft than one built up as a part of the outside wall. The effect of the cold winds upon an exposed chimney is to make an erratic draft. When a fire is started the column of cold air within the chimney must be forced out before the warmer and lighter gases can circulate. Occasionally this causes a smoking furnace or fire-place until the chimney becomes heated, and even then, the draft may continue to be sluggish as long as the cold wind strikes directly against the chimney wall. When the cold wind is not directly against this side of the house the conditions would not be noticeably bad. Inside chimneys are not subjected to such erratic conditions and are to be recommended for best furnace service. In making this recommendation the writer is not unmindful of the fact that the outside chimney has become very firmly established as an architectural feature in the home. There is no desire to change this attitude. The outside chimney lends itself not only to outside but to inside decorative effect and may be used whenever desired, with proper restrictions. First, if a consistent draft is demanded for all weather conditions, the chimney should be double walled on the outside at least as far up as the eaves; second, if the heating furnace is to be attached to this chimney flue, it should

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be done with a full knowledge that the draft may be bad just on those days when the best draft is desired. It should also be remembered that heat radiated by an inside chimney goes to heat the house but that from an outside chimney is a total loss.

Other points to be considered in chimney construction may be stated very briefly.

All chimneys should extend to the basement floor and should rest upon suitable foundations to prevent settling and cracking.

All furnace chimney flues should begin near the basement floor and should have convenient clean-outs at the lowest point.

No smoke connection should enter the chimney flue other than the furnace pipe.

All chimneys should extend two to three feet above the highest point of the roof. Those that are overshadowed by a nearby building may require a "cowl" to avoid downdraft when the wind blows over that building.

No woodwork of the building should be rigidly fixed to the chimney. This is frequently done and is the source of much annoyance in the raising and lowering of floors, doors, etc., as the expansion and contraction of the chimney takes place. In the winter when the house is at its least size, the chimney has expanded to its greatest length, and in summer the reverse conditions prevail. This requires the frequent trimming at top and bottom of all partition doors near the chimney to avoid binding, a condition which would not exist if the chimney were at liberty to expand and contract free from any house restrictions.

Summary: Residences throughout the country embody many structural imperfections that should and could be eliminated. The one type of residence which houses the vast majority of the people is the framed-wall type. This type is open to the greatest variety of interpretations as to what is good or what is bad construction. In an endeavor to create improved standards of construction and thus protect the average householder from unnecessary expenditures, as well as to assist in the conservation of a considerable portion of that $54,000,000 coal pile consumed annually in the state of Indiana as domestic fuel, all residents of the state should interest themselves in a movement toward the betterment of these conditions. Attention should be especially directed toward an improvement in the insulating qualities of the outer walls on all framed houses, toward the better protection of the windows against excessive inleakage, toward the flooring of all attic spaces, toward the sheathing of all studded walls located between any room and attic spaces, and toward the proper location and construction of the chimney flues.

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Electrical House Pumping Systems

C. C. BLALOCK and D. D. EWING

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ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

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ENGINEERING EXTENSION SERVICE

Electrical House Pumping Systems

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LAFAYETTE, INDIANA
SEPTEMBER, 1923

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ELECTRIC HOUSE PUMPING SYSTEMS

I. Introduction

The importance of an abundant and convenient supply of pure water in every household cannot well be overestimated, for on this depends to a great extent the health and happiness of every member of the family. Good water supplies have long been available to the city dweller but until recently the inhabitants of outlying and rural districts obtained the water needed for domestic purposes only at the expense of considerable time and labor.

With the coming into general use of electricity on the farm the advantages of electrically operated pumping systems are being recognized and the demand for such systems greatly stimulated. Electric motor driven pumping outfits are now available in all sizes, ranging from those suitable for a small summer cottage to those necessary on a large country estate.

Object of Bulletin. In the preparation of this bulletin the object has been to present pertinent information concerning the various electric motor driven water supply systems now on the market in such manner as to permit the intelligent selection and application of these systems; and, further, to present such information to the users of these systems as will enable them to secure the most satisfactory and efficient service after installation.

In furtherance of this object manufacturers' literature has been carefully studied, present owners of typical systems interviewed, installations inspected and tests made.

Acknowledgements. The authors are indebted to numerous householders who have kindly permitted inspection and test of their water supply equipment; to manufacturers who have furnished catalogues, operating data and pumps for testing purposes; to plumbing firms who have assisted in securing data and have given considerable information on practical matters; and to a number of seniors in the School of Electrical Engineering, Purdue University, who have assisted in making tests.

II. Water Supply Systems

Water supply systems which make use of electric motor driven pumps may be divided into two groups:

(1) Direct pressure systems,
(2) Storage tank systems.

To the first group belong those systems which either do not employ storage or employ such a small tank that its value for storage is negligible, the tank serving only to equalize the pressure. Systems belonging to the second group employ a tank of such

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size that the capacity of the system to meet unusual demands is not altogether dependent upon the capacity of the pump.

The advantage claimed for the direct pressure system is that the water always comes direct from the source and has no opportunity to grow warm or stale. That this is a distinct advantage is evident from the efforts of the manufacturers of storage systems to provide special means by which, when desired, water may be obtained direct from the well. Several of these systems are now provided with means for by-passing the tank when fresh water is desired.

The storage tank system is of particular value from the standpoint of fire protection. A system of ample size to meet all domestic requirements usually would not have sufficient capacity to enable fire fighting to be done effectively if its capacity depended upon the pump alone. This deficiency can be supplied by use of a storage tank of sufficient capacity to provide the water needed for such emergencies.

Displacement Pumps. Pumps which make use of a piston working in a cylinder are known as displacement pumps. Such, ordinarily, are used with both the direct pressure and the storage systems. They are made in two types, the shallow well or cistern type and the deep well type.

Pumps of the first type operate as combined suction and force pumps and may be placed in any convenient location with respect to the source of supply so long as the practical limit for suction lift, 20 feet, is not exceeded. Loss in head due to friction in the suction piping should be included where the suction line does not run directly from the pump to the water source.

The deep well type of pump is used where the water level in the well is below the practical suction limit. In this type the pump cylinder is placed in the well, usually below the water level, and the piston connected by a "sucker-rod" to a "power head" at the top of the well. The power head changes the rotary motion of the driving motor into the reciprocating motion of the pump piston.

Either of the above types of pump may be used with an automatic water supply system, the driving motor being governed by a pressure-controlled switch. The amount of water which can be drawn before the pump begins to operate depends upon capacity of the tank as well as the adjustment of the automatic switch.

Pneumatic Pumps. The pneumatic system makes use of a tank for storage of compressed air. The pump is located below the water level in the well or cistern, and operates only when a faucet in the discharge line is open. With this system an electric motor is used to drive the air compressor. The action of the motor is commonly controlled by a switch actuated either from the pressure in the water line or from that in the air line. It is not usual with this system to provide for water storage beyond that needed for a small pressure chamber which serves to "smooth out" the pulsations in the flow of water from the pump. If the operation of the compressor is made to depend upon the pressure

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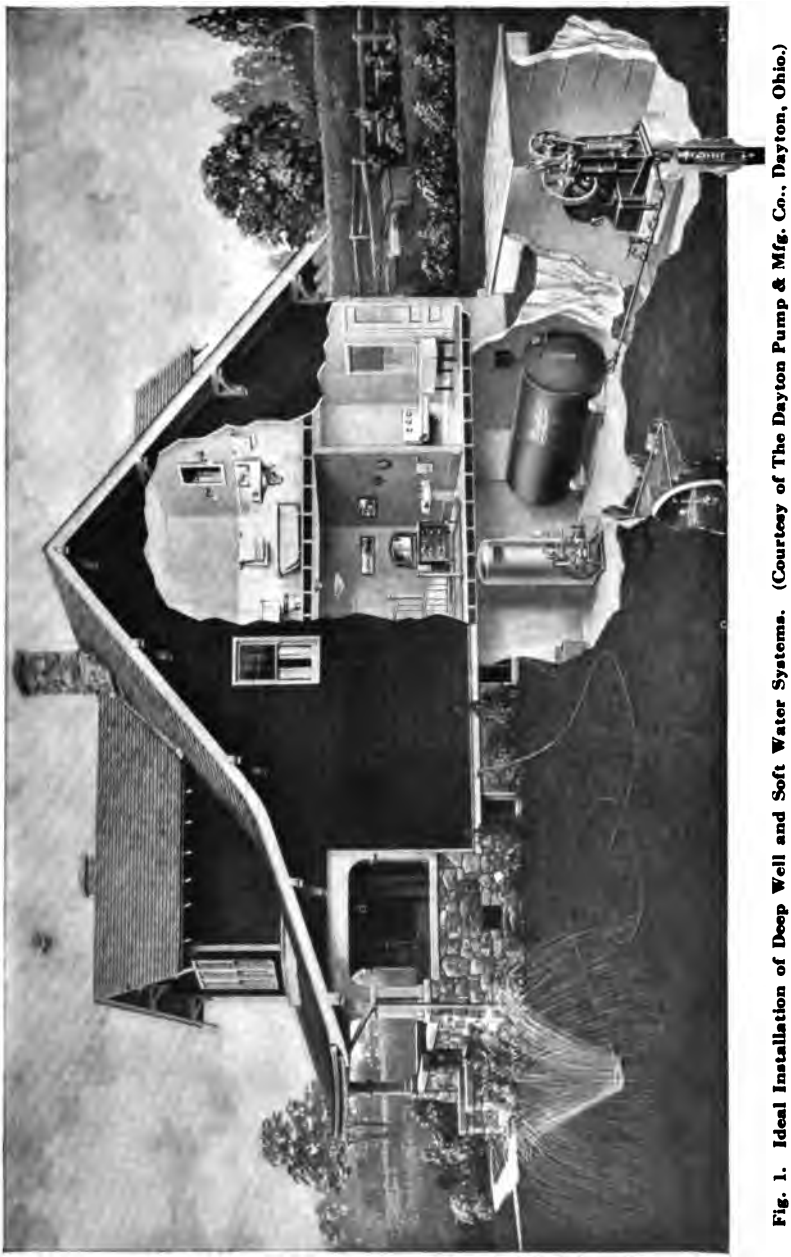


Fig. 1. Ideal Installation of Deep Well and Soft Water Systems. (Courtesy of The Dayton Pump & Mfg. Co., Dayton, Ohio.)

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in the air tank and this tank is of large capacity, then a reserve is provided similar to that provided by a large water tank; i. e., considerable water may be drawn from the system before the output becomes directly dependent upon ability of the compressor to maintain the air pressure.

The actual pumping of water is done by an arrangement of floats and valves contained in a chamber located below the water line in the well or cistern. When the pressure in the discharge line is reduced by the opening of a faucet or valve the compressed air automatically forces water from the chamber into the discharge line. The air in the chamber is then released, the chamber fills again with water which is immediately discharged through renewed pressure from the air line; the operation continuing until the discharge line is closed and the original pressure re-established.

Advantages claimed for the pneumatic systems are that the water always comes fresh from the well and cannot become warm or stale, and that a single air compressor and tank may be used for both hard and soft water supply by piping the air to independent pumps at the two sources of supply.

Capacities. The pumps furnished with systems intended for supplying the domestic needs of a small family usually have capacities of 120 to 150 gallons per hour. For larger families, or for supplying water for sprinkling, watering stock, etc., larger capacities are recommended. For the general needs of an average household, including lawn sprinkling and similar requirements, a capacity of 250 to 400 gallons per hour is advisable; while for large residences, farms, estates and public institutions capacities of 500 to 1000 gallons per hour should be provided.

At present it is a common practice to use the capacities of pumps and tanks indicated in the following table for the several services enumerated.

TABLE 1.
PUMP AND TANK SIZES FOR DIFFERENT SERVICES

Kind of Water	Service	Plumbing Fixtures	Pump Size Gal. Per Hr.	Tank Capacity Gallons
Soft Water	Residence	One bath and other fixtures	120	50
Hard Water	Residence	One bath and other fixtures	150	220
Soft Water	Residence	Two baths and other fixtures	150	220
Hard Water	General Farm	One bath and other fixtures	360	220
Hard Water	Large residence, estates, etc.		720	Tank dependent on conditions

The tank sizes indicated in this table are, in the case of the larger systems, too small to secure the best operating conditions as they require the pump to operate too frequently. Where water is used for drinking purposes, however, the use of larger tanks is likely to result in stale or insipid water unless some special arrangement is provided for obtaining water direct from the well for this purpose.

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If no storage tank is used it will be necessary to provide pump capacity sufficient to meet the greatest demand which is likely to occur, otherwise the pressure will be so reduced, during this period of heavy demand, as to render the system unsatisfactory. If a tank is provided, however, a smaller pump may be used, the tank storage being available to supply demands above the average.

It should be borne in mind that the compression tank capacity as given in the manufacturer's catalogue does not represent the actual amount of water which can be stored; nor does this in turn represent the actual amount of water which may be drawn from the tank under pressure. For normal conditions the upper third of a compression tank will be occupied by air, the elasticity of which drives the water out through the discharge line. While the water is being discharged from the tank the air is expanding and its driving force being reduced, so that the lower limit of effective pressure is reached before the tank is emptied. For instance, a 180 gallon tank is intended to store only 120 gallons of water, the remaining space being occupied by air. Assuming the tank pressure to be at the upper limit, usually about 50 lb. per sq. in, approximately 50 gallons may be drawn before the pressure has been reduced below a practical working value of say 20 lb. per sq. in. Thus, for storage purposes, the tank is seen to have a capacity of only 50 gallons, instead of the 180 gallons at which it is rated.

The rule for calculating this storage capacity is: *Add to the highest pressure* 15; *multiply the sum by the air space in the tank at the highest pressure in gallons; divide the product by* 15 *plus the lowest pressure; subtract the original air capacity.* The result will be the effective water storage in gallons. Thus in the above example, $180-120=60$ gal. = Air Space. $\frac{(50+15)\times 60}{20+15}-60=50$ (approximately). The effective capacities of tanks of different sizes may be computed also from the following table, the illustrative examples showing how the table is used.

TABLE 2.

WORKING CAPACITIES OF PNEUMATIC TANKS.*

Percent of Tank Capacity Available.

Final Gage Pressure Lbs. per Sq. In.	Initial Gage Pressure—Pounds Per Square Inch									
	10	20	30	40	50	60	70	80	90	100
5	8	25	41	58	--	--	--	--	--	--
10	0	13	26	40	53	66	--	--	--	--
15	--	5	16	28	39	50	61	--	--	--
20	--	0	9	19	29	38	48	57	--	--
25	--	--	6	12	21	29	37	46	54	62
30	--	--	0	7	15	22	30	37	44	52
35	--	--	--	3	10	17	23	30	37	43
40	--	--	--	0	6	12	18	24	30	36
45	--	--	--	--	3	8	14	19	25	30
50	--	--	--	--	0	5	10	15	20	25

*Fort Wayne Engineering and Manufacturing Company, Bulletin, No. 5006.

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Example 1:

A 630 gallon tank, 36 inches in diameter by 12 feet long, is 2/3 full of water under a gauge pressure of 60 pounds. How much water can be drawn before the pressure reaches 20 pounds?

Between 60 and 20 pounds the table gives 38 per cent. Therefore $0.38 \times 630 = 239$ gallons available.

Example 2:

What size tank must be used to deliver 500 gallons of water from storage when tank is 2/3 full under 80 pounds pressure, if the lowest permissible water pressure is 30 pounds?

Between 80 and 30 pounds the table gives 37 per cent. The tank must therefore have a capacity of $500 \div 0.37 = 1350$ gallons or it should be about 48 inches by 14 feet

Example 3:

A 720 gallon tank 42 inches by 10 feet is 2/3 full of water under a gage pressure of 50 pounds. · What will be the pressure after 150 gallons have been drawn?

150 gallons equal 21 per cent of the tank capacity. Corresponding to the 50 pounds initial pressure, and 21 per cent working capacity, the table gives final gage pressure as 25 pounds.

The overhead storage tank, on the other hand, has its full capacity available for actual water storage and maintains a suitable working pressure to the lower limit of its capacity. This advantage is usually off-set however in small systems by the higher cost of the overhead tank and its greater liability to cold weather difficulties.

Motors. The power rating of the motor will of course be dependent upon the capacity of the pump and the pressure against which it is to operate. For the smaller systems 1/8 to 1/4 horsepower motors are sufficient, while for the larger outfits ratings of 1/2, 3/4, or 1 horsepower are necessary.

For a family of four or five in a house with one bath tub and the ordinary plumbing fixtures, a pumping outfit consisting of a 120 gallons per hour pump, pressure range 20 to 40 pounds per square inch, and a 50 gallon tank is a common installation. Such a pump, ordinarily, should be equipped with a 1/6 horsepower motor.

The horsepower required may be calculated as follows: *Add to the suction lift in feet the product, pressure in pounds per square inch times* 2.3. *Multiply this sum by the gallons per minute pumped and divide by* 1000. This rule gives approximate results. It is based on a pump efficiency of 25 per cent and it neglects part of the friction losses in the piping. For efficiencies other than 25 per cent the divisor in this rule should be 4000 times the pump efficiency. To illustrate the application of this rule let it be required to find the size of motor necessary to drive a 120 gallon per hour pump (two gallons per minute) when the suction lift is 20 feet and the pressure is 40 pounds and the pump efficiency is 30 per cent. $\frac{(20+2.3\times 40)\times 2}{4000\times .30} = 0.187$ hp.

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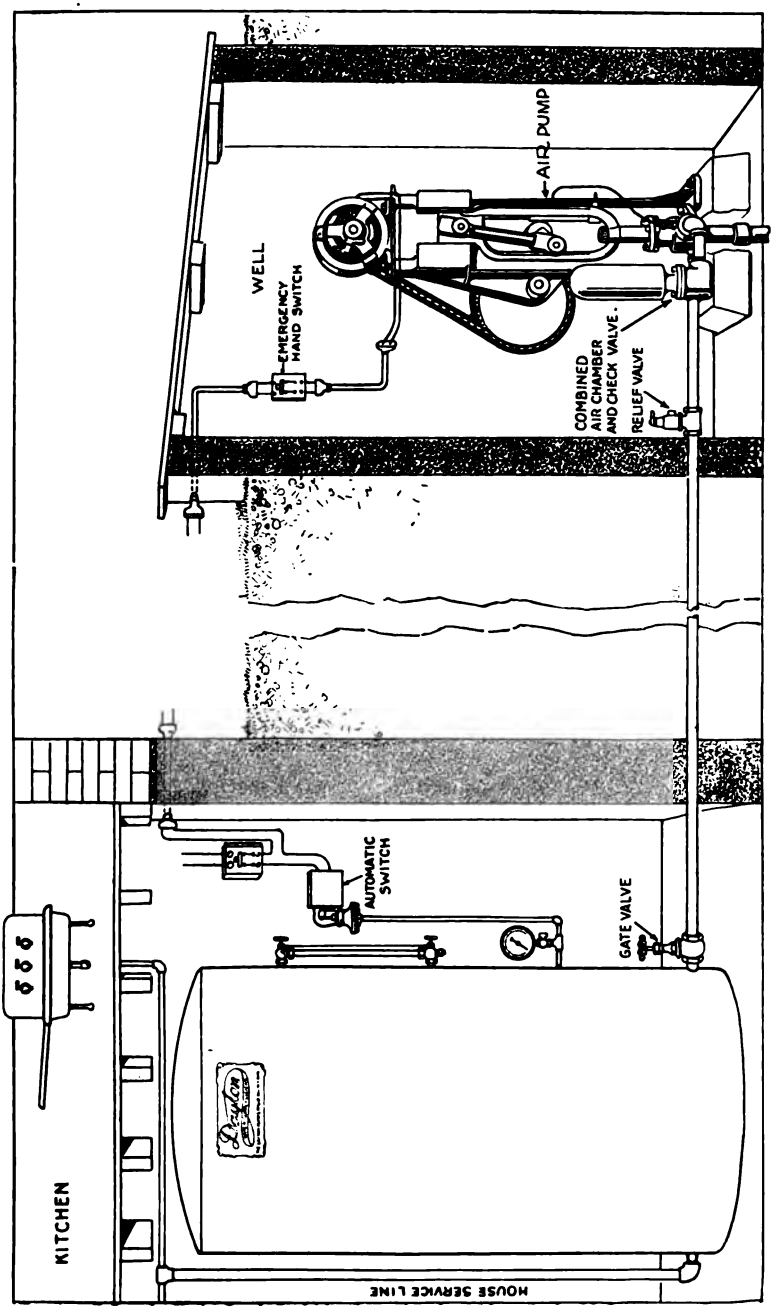


Fig. 2. Ideal Installation of a Deep Well System. (Courtesy of The Dayton Pump & Mfg. Co., Dayton, Ohio.)

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As this is more than 1/6 horsepower, the next larger size, a 1/4 horsepower motor, should be used.

Motors are designed for operation at standard voltages from direct or alternating current supply. In ordering it is necessary of course to specify the voltage and kind of current available. The ordinary 32 volt farm lighting outfit can usually supply up to 1/4 horsepower without danger of serious overload. For larger motor ratings the effect upon the generator and batteries of the lighting system must be carefully considered in order to be sure that adequate power may be safely secured. In the city, where these systems are used for furnishing soft water supply, power for the smaller motors may safely be taken from any convenient lighting circuit, this power being commonly 110 volts, alternating current.

Regardless of the character of the available power supply the motor should be able to exert a large starting effort since displacement pumps must start up under heavy load. The speed should be fairly constant for different loads. For direct current operation these requirements are best met by a compound motor, which is the type commonly supplied by manufacturers. For single phase alternating current power the repulsion-start type of induction motor has the most satisfactory starting and running characteristics, while for three-phase alternating current power the wound rotor type of induction motor is most suitable, particularly for the larger systems. For small units operating from three-phase supply a properly selected squirrel-cage type induction motor can be arranged to operate satisfactorily. Such a motor should have sufficient resistance in the rotor to give the necessary starting effort.

Control and Protective Apparatus. The compression tank system of water supply lends itself very readily to automatic operation. The control apparatus for smaller systems is very simple, involving only a line switch actuated by the pressure of the water or air in the tank. This arrangement allows the pressure to vary between certain fixed limits these limits being adjustable in most cases by alteration of the pressure of a spring. A common range of pressures, as recommended by the manufacturers, is from 35 to 50 lbs. per sq. in. This means that the automatic controller will operate to start the motor when the tank pressure has dropped to 35 lb. per sq. in. and stop it again when the pressure has risen to 50 lb. per sq. in. The pressure will be adequate then so long as a normal amount of water is being drawn from the system. In case of an unusually heavy demand the rate of outflow may exceed the pumping rate and the pressure will then drop below 35 lb. The pump will start to operate at the 35 lb. per sq. in. pressure, however, and continue to operate, regardless of how low the pressure may run, until the period of heavy demand has passed and the pressure again reaches the upper limit of 50 lb. per sq. in. It is thus evident that the ultimate capacity of the system is represented by the

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capacity of the pump to supply water at or below the lower pressure limit.

For larger systems it is necessary to operate the line switch by means of a relay and to insert a step or two of resistance in series with the motor while it is starting. The relay for these systems may be actuated by a diaphragm arrangement or by a pressure gage of standard design so arranged that the indicator hand closes the electric circuit actuating the relay at the predetermined points.

The apparatus as above described is very reliable but the result of a single failure would probably prove disastrous to the motor, and possibly to other parts of the system. It is therefore advisable to guard against possibility of damage from this source in two ways: by fuses in the electric line leading to the motor, of such rating that they will "blow" and break the circuit before a dangerous current is reached; and by a pressure-controlled relief valve in the main water line near the tank which will open automatically before the tank pressure becomes too high for safety.

The fuses and relief-valve form the only protective apparatus necessary for small outfits but the motors of larger systems, operating from city or transmission line circuits, should in addition be protected by suitable apparatus for opening the line circuit against loss of line voltage, continued low voltage, and in some cases against damage by lightning.

III. Operating Features

Advantages of Electric Drive. There are numerous advantages gained through the use of electricity, rather than other sources of power. The electric motor occupies less floor space than any other driving mechanism, is exceedingly dependable, quiet in its operation, clean and gives off no objectionable fumes. Its use involves the presence of no explosives and if properly installed the fire risk due to its presence is negligible. Moreover, as previously pointed out, its operation can readily be made automatic, and when this is done the system requires only occasional inspection and oiling to be kept in perfect operating condition.

The electric motor drive is also an inexpensive method provided power can be obtained from an electric power line at a reasonable rate. When the power is supplied from a farm lighting system the cost is likely to be considerably greater. Careful consideration should be given also to the possibility of overloading the small power plant, since these systems are usually of rather low capacity. There is on the market a combination lighting and water system which obviates these difficulties by using one gas engine to drive both generator and pump, the three machines being located on one bedplate with the engine in the center and arranged for coupling to the generator on one side and pump on the other.

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Where gas engine drive is used a larger storage tank is advisable than would be necessary for a motor operated system since the gas engine system cannot readily be made automatic. It can easily be arranged for self-stopping by providing means for breaking the ignition circuit when the pressure has reached a predetermined point but it cannot well be made self-starting. It therefore becomes desirable to provide large enough storage capacity to require operation of the pump only at convenient intervals.

Water Sources. Any available source of water may be used, provided the presence of foreign matter does not render the water corrosive or obstruct the water passages in the pump. In the case of running streams the large variation in suction lift may render operation somewhat difficult at times.

Where the water source is a well it is advisable to make an approximate determination of the amount of water the well is able to supply and what the maximum range in water level will be, particularly for the larger systems. If the maximum suction lift exceeds twenty feet it is advisable to place the pump in a pit or to use a deep-well type of pump. For domestic service the well, if a drilled one, should not be less than four inches in diameter. Where a deep well pump is necessary a six inch well is preferable.

Where both hard and soft water are to be provided and neither lift is more than twenty feet, an economical arrangement may be effected by using two tanks with a single pump and motor. This arrangement is objectionable only to the extent that it requires operation by hand of the valves necessary for shifting the pump from one system to the other. If a deep well type pump is required for the well water supply this arrangement could not be used. Another arrangement is to use a water motor for the soft water supply, the pressure from the motor operated well-water system supplying the power for operating the soft water system. The two systems would then be automatic and practically independent of one another. This is not, however, a very economical arrangement and two independent systems operated by separate pumps and motors usually will give more satisfactory results.

Suction Lift. By suction lift is meant the difference in elevation between pump cylinder and the water surface, plus the pipe friction, plus the back pressure of the foot-valve, all expressed in feet of head or the height of a water column necessary to overcome them. Since this lift depends on atmospheric pressure it is affected by altitude. At sea level the atmospheric pressure will support a column of water 33.94 feet in height, this height decreasing about 1.2 feet for each 1000 feet of elevation above sea level. However, since the pipe friction and back pressure of the foot valve under ordinary working conditions are considerable, lifts of 25 feet are about the maximum which can be attained in practice and it is usually not advisable to exceed 20 feet.

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In general the suction lift should be made as small as possible in order to avoid difficulties due to loss of priming by the pump.

Deep well cylinders are ordinarily placed below the water surface and therefore have no suction lift, the water entering the pump chamber under a small head.

Pressure Head. Pressure may be measured either in pounds per square inch or in feet of head and consists chiefly of the difference in elevation between the pump chamber and the level to which the water is being pumped, or its equivalent pressure in pounds per square inch, plus the frictional resistance which the pipe offers to the water flow. Head in feet may be converted to pounds per square inch by dividing by 2.3.

The frictional resistance depends upon the size, shape, kind and condition of the piping and the velocity of the water. Its value is obtained from experimental formulas and is given by pump manufacturers in the form of tables covering different sizes of pipe with water flowing at various velocities. One such table is here included. Piping should be of ample size and arranged to give as direct connection as possible between points to be supplied in order to reduce the loss of head from this source.

TABLE 3.

FRICTION LOSSES IN IRON PIPES*

Pounds Per Square Inch.

Capacity Gal. per Hour	Size of Pipe	Length of Pipe in Feet			
		100	200	300	500
100	½ Inch	1.9	3.8	5.7	9.5
	¾ "	0.5	0.9	1.4	2.3
	1 "	0.1	0.3	0.4	0.7
180	¾ Inch	1.4	2.8	4.2	7.1
	1 "	0.4	0.9	1.3	2.1
	1¼ "	0.1	0.2	0.3	0.5
360	¾ Inch	5.1	10.2	15.3	25.6
	1 "	1.6	3.1	4.7	7.8
	1¼ "	0.4	0.8	1.2	1.9
720	1 Inch	5.6	11.2	16.8	28.1
	1¼ "	1.4	2.8	4.2	7.1
	1½ "	0.7	1.3	2.0	3.3

*Fort Wayne Engineering and Manufacturing Company.

The loss in a short radius 90 degree elbow may be taken as the loss in a straight pipe equal in length to 40 times the diameter of the elbow; the friction of a return bend equal to twice that of a short radius 90 degree elbow; and the friction of a valve equal to that of a return bend.

The pressure gage reading will include the pipe friction loss as well as the actual elevation head if the gage is placed near the pump or tank. The actual head at the point of discharge will then be the gage reading minus the difference in elevation between the gage and the point of discharge, minus the pipe friction loss, all expressed in the same units, i. e., pounds per square inch or equivalent feet head.

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For domestic service a pressure at the pump or tank of 40 lb. per sq. in., corresponding to an elevation head of 92 feet, gives very satisfactory results. Lower pressures than 25 lb. per sq. in., are likely to prove unsatisfactory.

Water Consumption. Estimates of the amount of water required should be very carefully made and a liberal allowance made for extra demand, since considerably more water will be used after the system is installed than formerly, particularly if a sewage disposal system with its accompanying conveniences is also installed.

Water consumption figures are, in general, very indefinite, and are subject to considerable error. For domestic service alone it appears advisable to provide from 25 to 50 gallons per person per day, depending to some extent upon how many people are to be supplied. In general the per capita consumption for a large group of people will be less than for a small family. In addition to domestic requirements allowance must be made for lawn sprinkling and, in case of country homes, for watering of stock.

Estimates of water requirements for various purposes compiled from a number of sources are as in the following table

TABLE 4.

1. Watering Stock—

Animal	Gal. per Day
Horses	7 to 10
Cattle	7 to 12
Hogs	2 to 3
Sheep	1 to 2

2. Sprinkling Purposes—
A ¾ in. hose at 40 lb. per sq. in. pressure will deliver 6 gal. per min. with a solid stream and 4 gal. per minute with a spray.
To sprinkle 100 sq. ft. of lawn requires 8 gallons of water. To soak 100 sq. ft. of lawn requires 15 to 40 gallons of water.

3. To Operate Plumbing Appliances—

Appliance	Water in Gallons
To flush a water closet	6 to 10 gal.
To fill a bath tub	20 to 40 gal.
To fill a lavatory	1 ½ gal.

IV. Selection, Installation and Maintenance

Determination of Size. In determining the system needed for a particular case it is necessary to decide upon the amount of water needed per day, the pressure under which it is to be delivered, tank capacity—if a storage system is to be used—and pump type and capacity. The available power supply will determine the type of motor to be used and the motor horsepower will depend upon pump capacity and pressure.

Manufacturers of water supply systems recommend that an outline of requirements and conditions be submitted to them, leaving to their judgment the selection of proper equipment. It is well to submit such an outline as a check, but the customer should make an independent estimate, since he is better informed as to conditions under which the system will have to operate. If serious differences are found to exist between his own and the

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manufacturer's choice, the cause should be located and fairly close agreement reached before final decision is made.

In order to illustrate the method by which an estimate can be made the following example is given:

Assume that the domestic requirements of six people are to be met; the house being fitted with modern conveniences, including a sewage disposal system. Assume that in addition lawn sprinkling and the watering of ten horses and five cows are to be provided for.

By reference to the preceding section on water consumption, the following table can be made up.

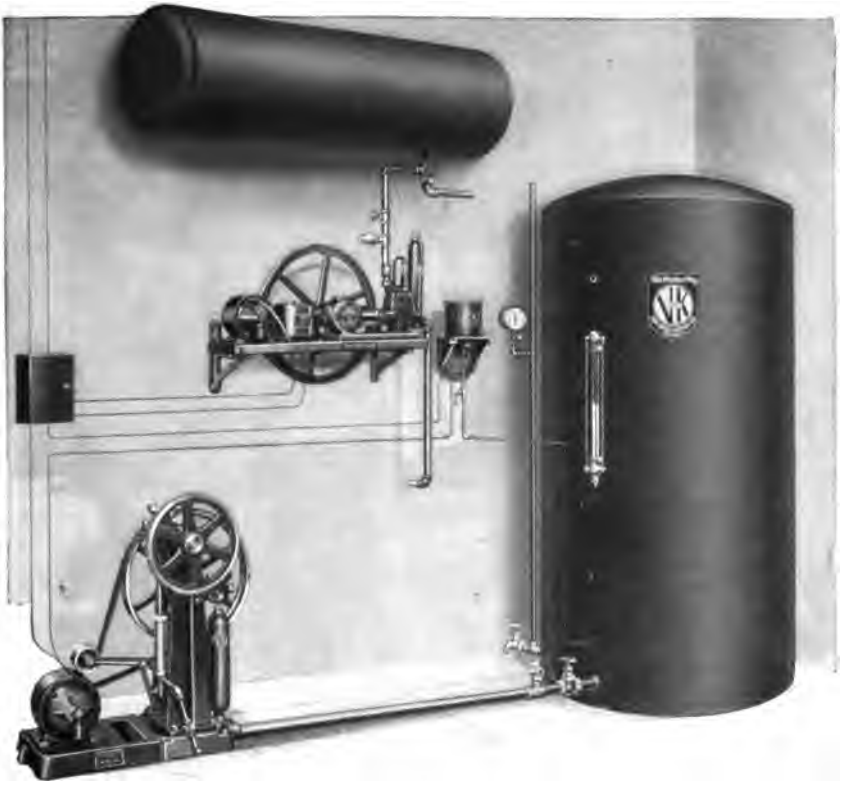


Fig. 3. Basement Installation of a Deep Well and Soft Water System. (Courtesy of the The Valle-Kimes Co., Dayton, Ohio.)

TABLE 5.

6 people at 40 gallons per person	240 gal.
10 horses at 10 gallons each	100 gal.
5 cows at 12 gallons each	60 gal.
Sprinkling, one hour at 6 gals. per minute	360 gal.
Total	760 gal.
For extra demands	240 gal.
Total daily demand	1000 gal.

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If this demand was uniformly distributed over the average working day of ten hours a 100 gallon per hour pump, operating continuously would supply the demand. Since this is never the case however, it is necessary to estimate the largest sustained demand and provide either a larger pump or a tank of sufficient capacity to tide over this period.

It is probable that the largest sustained demand will be that due to sprinkling, the estimated time required being one hour at a rate of 6 gallons per minute. This will require an available supply of 360 gallons of water at good pressure. Assuming that the pressure may be allowed to vary between 50 and 30 pounds and referring to the table of working capacities of tanks on page 9 it is found that the tank should have a total capacity of $360 \div 0.15 = 2400$ gallons, or a tank about 5 ft. in diameter by 16 feet long will be required. A tank of this size would also be able to handle at other periods of the day a demand equivalent to the discharge of one faucet running continuously for one hour, two faucets running continuously for thirty minutes or three faucets running continuously for twenty minutes; each faucet discharging at the rate of six gallons per minute. It is assumed, of course, that in each case the tank is initially filled to its normal capacity at 50 lb. pressure, which will not always be the case since the automatic switch will start the pump motor only when the pressure has dropped to 30 lb.

The pump should be able to restore the tank pressure to its maximum value in 1 1/2 to 2 hours time, which will require a pump with capacity of about 200 gallons per hour.

The objection to the system as outlined above lies in the fact that the pump alone will be unable to supply at satisfactory pressure a single faucet or hose running continuously, and if a heavy demand comes when the tank pressure is near its minimum the resulting pressure is likely to prove unsatisfactory.

The alternative lies in providing a pump of sufficient capacity to maintain good pressure under normal sustained demands, and a tank large enough to act as a reserve against unusual demands of short duration. In the example under consideration a pump with capacity of 360 gallons per hour may be specified. This will insure at all times capacity enough to keep a single hose or faucet running at fair pressure. Then if a tank of 300 gallons be provided there will be available, at a maximum pressure of 50 lb., a reserve of $300 \times 0.15 = 45$ gallons before the pump begins to operate. This is sufficient to handle an equivalent of one faucet running continuously for 7½ minutes.

In case the so-called "tankless" or "direct-pressure" system is decided upon a tank of about 25 gallon capacity is still advisable in order to provide elasticity for the system and prevent operation of the pump by reason of leaky fixtures, etc. This capacity tank will then provide a reserve of about 3 1/2 gallons which will be sufficient to "cushion" the motor operation.

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The average head against which the pump will discharge will be $\frac{50+30}{2}$ = 40 lb. per sq. in. = 92.5 ft. approximately. Adding 20 ft. for suction lift and 2.5 ft. for pipe friction the total average head against which the pump must operate is 115 ft. Since the pumping rate is to be 6 gallons per minute, the horsepower output will be approximately $\frac{115\times6}{4000\times.35}$ = 0.49 hp. or slightly less than 1/2 horsepower, allowing for a pump efficiency of 35 per cent. It should be noted however, that it is not usually necessary to specify the motor since the complete outfit is commonly purchased from one manufacturer, who assumes responsibility for furnishing the proper motor. All that is necessary then is to advise the manufacturer as to pump and tank capacities desired and total head against which the pump is to operate. In case the suction lift is below twenty feet a shallow well type of pump is used and if above twenty feet a deep well type is necessary. With pneumatic types of pump there is no essential difference between the pumps for shallow or deep wells, though the shape of the pump differs in some cases.

Installation. Specific directions for the installation of all apparatus connected with the water supply system are usually furnished by the manufacturer, and careful consideration should be given these directions since the manufacturer is in position to know how to secure the best results from the apparatus. In general, the first consideration should be to secure immunity from troubles due to freezing. The second consideration should be directed towards a location convenient alike to the source of supply and the points of maximum demand, in order to avoid unnecessary losses in piping. Both of these considerations are usually best met by locating the pump in the basement of the house. If the basement is of sufficient size the entire outfit may be placed there; if not, then the tank may be buried in the earth outside with one end projecting into the basement.

If a small tank is used, such as furnished with soft water outfits, the complete equipment will occupy very little space and may be set directly upon the basement floor, or with some designs, the pump and motor may be placed on wall brackets while the tank is suspended in a horizontal position from the floor beams above.

Large tanks are arranged for horizontal setting and should be placed on concrete piers, shaped to cradle form. These piers should be placed three to five feet apart and should be of sufficient height to leave a clear space of at least twelve inches between tank and floor. Where the tank is placed outside the basement the earth underneath it should be carefully tamped to prevent settling and the head should extend two to four feet into the basement, depending upon the size of the tank.

If necessary to locate the outfit away from the house a pit, six to ten feet deep, should be provided, properly lined and cov-

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ered. The lining should be of concrete or cement in order to prevent leakage of water into the pit, the sides extending sufficiently above ground to permit the placing of air-vents beneath the cover. The pump should be so placed that it will not have to carry the weight of the suction pipe.

All piping should be galvanized to prevent rusting, with joints made thoroughly water tight, and if outside should be placed at least three feet below ground to insure against freezing. All pipe should be run as direct as possible to avoid unnecessary loss of pressure. The suction piping should have a slight upward slant from the well to the pump in order to guard against the collection of air into pockets with resulting priming difficulties.

If a shallow-well type of displacement pump is located in a basement or pit in such a manner that the pump suction is below the level of the water in the well or cistern outside, trouble may be experienced in keeping enough air in the chambers attached to the pump as well as in the pneumatic tank. The purpose of the chambers is to act as cushions to promote smooth operation.



Fig. 4. An Electric Pump in a Farm Basement.

If the chambers become filled with water instead of air the pump will no longer operate smoothly, but will be subject to knocks and jars which are likely to prove detrimental. This difficulty may be avoided by installing a small standpipe between pump

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and cistern. Then by throttling the water before the standpipe is reached air will be drawn through the standpipe. This should be done as often as necessary to provide smooth operation of the pump and keep sufficient air in the storage tank.

Occasionally it may be necessary to install extra air chambers where the length of pipe is considerable and a tendency toward "water-hammer" is shown. Air chambers used in this way always have a cushioning effect and tend to promote smooth operation.

Check valves or foot valves are desirable in the suction line where the total lift exceeds fifteen feet, and may prove necessary in some cases for smaller lifts. They hold the suction pipe full of water while the pump is idle thus rendering the priming easy. Where footvalves do not provide the necessary relief it may be necessary to install a small by-pass around the pump so that the suction pipe may be filled from the storage tank. This should insure proper priming unless there are excessive air leaks in the line or unless foot valves are very leaky. It should be kept in mind of course that suction lifts should always be limited as much as possible and never under any circumstances should exceed 25 feet.

The shallow well type of pump may be located where most convenient without other reference to location of the water source than to remember that extra length of piping adds to the suction lift, due to friction of the water flowing through the pipe, and increases the likelihood of troublesome air leaks. Any additional elevation of course adds directly to the suction lift.

Deep well pumping equipment is not so flexible as to location. Due to its method of operation the pump itself must be located below the water level in the well and the power head directly above. The power head and driving motor may be located at ground level with a housing built over it, but since this involves more or less danger from freezing a better arrangement is to provide a pit as previously described into which the equipment may be placed. The illustration on page 11 shows an arrangement of this kind.

The pneumatic system compares favorably with the shallow well type as to flexibility of location. While the pump proper is located below the water level in the well the connection between the pump and air tank or compressor consists of a pipe line which may be extended as desired. The same objection to unnecessary separation holds as in the case of the shallow well type of pump however. Friction in the water pipe adds to the head against which the pump must operate and friction in the air pipe decreases the power available to do the pumping. In addition it is difficult to prevent some loss of air from leaks in the pipe line. As noted previously one compressor and air tank may be used to supply water to two otherwise independent systems, as, for instance, cistern and well water systems. All that is necessary is to provide a pump in both well and cistern and

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run pipes to these pumps from the common source of compressed air. The water lines will be entirely independent, running directly to the house piping of the two systems.

Electric motors must be properly wired and must have the proper voltage applied to them if they are to operate to best advantage. The most frequent source of difficulty is due to low voltage at the motor. This will result in excessive heating of the motor and may result in burning it out. This under-voltage may be due to the supplying transformer being overloaded or may be due to use of too small wires, resulting in excessive loss of electric pressure before the motor is reached. It is particularly necessary to guard against loss of pressure in the wiring in case of farm lighting sets, the voltage being lower in this case than where power is secured from a large power system. The current is proportonally larger, resulting in greater pressure losses in the wiring unless large wire sizes are used.

The wires should be brought through a line switch and fuses of proper size installed as a protection to the motor in case it should become stalled or overloaded. The motor wiring should be separate from the lighting circuits in all cases.

The following table shows the proper sizes of wiring and fuses for various motor capacities and power sources.

Table 6
WIRE AND FUSE SIZES.

Distance		110 Volts Single Phase		32 Volts Direct Current	
		100 Ft. or Less	100 Ft. to 200 Ft.	50 Ft. or Less	50 Ft. to 100 Ft.
⅛ Hp Motor	Wire	No. 14	No. 12	No. 12	No. 10
	Fuse	5 Amp.	5 Amp.	15 Amp.	15 Amp.
¼ Hp. Motor	Wire	No. 12	No. 10	No. 10	No. 8
	Fuse	10 Amp.	10 Amp.	20 Amp.	20 Amp.
¼ Hp Motor	Wire	No. 12	No. 8	No. 8	No. 6
	Fuse	15 Amp.	15 Amp.	25 Amp.	25 Amp.
½ Hp Motor	Wire	No. 10	No. 6	No. 6	No. 4
	Fuse	20 Amp.	20 Amp.	50 Amp.	50 Amp.
1 Hp Motor	Wire	No. 8	No. 6	No. 2	No. 1
	Fuse	30 Amp.	30 Amp.	90 Amp.	90 Amp.

Maintenance. Outfits of the kind under consideration require very little attention after installation if properly located and installed in the first place. This should not, however, be taken to mean that they may be forgotten entirely and expected to go on supplying satisfactory service indefinitely. A careful inspection should be made at least once each week to see that all accessible parts are in proper working condition, and well lubricated. Upon appearance of any abnormal condition, however slight, an investigation should be made at once to determine and remove the source of trouble. A slight adjustment made at once may save considerable expense later on.

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A frequent source of trouble with the shallow-well type reciprocating pump lies in the piston rod packing. If this packing is improperly placed or is too loose water will leak past it. If too tight the motor must supply additional power to overcome the resulting friction, this power being wasted as far as useful work is concerned. It may also result in scoring of the piston rod. If properly packed when installed renewal should not be necessary more often than once a year, or even less frequently, but the packing should be tightened slightly whenever an appreciable amount of water begins to leak past it.

Another source of trouble lies in the tendency of compression tanks to become "water-logged," this condition being caused by air leaving the tank through absorption by the water faster than it is supplied. With large tanks it is sometimes necessary to occasionally force air into the tank by means of an auxiliary hand or power pump, but many of the smaller outfits are equipped with a device in connection with the pump which permits a small amount of air to be drawn in at each stroke of the piston. This device is usually adjustable as to amount of air supplied. The water-logged condition results in too frequent operation of the pump. In extreme cases the pump operates each time a faucet is opened and shuts off immediately after the faucet is closed. Normally the air should occupy about one third of the tank capacity when pressure is at its maximum.



Fig. 5. A Shallow Well System. Capacity 360 Gal. Per Hour. (Courtesy of Ft. Wayne Eng'g & Mfg. Co., Ft. Wayne, Ind.)

The motors furnished with these equipments are not usually designed for continuous operation and may become overheated if operated for longer than 1 1/2 to 2 hours without shutdown. It is also expected that they will have free contact with the air for keeping the motor cool and they should not therefore be

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covered or placed so that the air cannot pass freely around the motor parts.

In case of direct current motors the commutators may become dirty and need occasional cleaning in order to prevent sparking. This may be done by holding a strip of fine sandpaper against the commutator while the motor is running. Emery cloth should never be used for this purpose as it cuts into the commutator itself. Brushes should be renewed when badly worn, the new brushes being fitted to the commutator by the use of sandpaper held on the commutator and rubbed back and forth on the lower side of the brush while power is cut off from the motor.

The automatic control switch should not ordinarily need attention but may be readjusted in most cases if it does not maintain a proper working pressure. The contact points should be inspected occasionally to see that they are not wearing excessively due to imperfect contact, lack of proper contact, lack of proper contact pressure or other reasons.

The manufacturer's instructions as to care of apparatus, particularly as to lubrication, form the best guide in most cases. The instructions so issued should be carefully memorized, or, better still, the instruction sheets or placards placed permanently near the apparatus concerned so that they are available for reference at all times.

Finally, the apparatus should be kept free from dirt, dust or excessive moisture and protected against rust by judicious application of paint or oil.

V. Operating Records and Tests

Energy Consumption. In order to determine the energy consumption of some typical plants, watthour meters were installed in four residences using automatic compression tank systems, for soft water supply, and left in place about six weeks. This period included the holiday season when it might be expected that more than an average amount of water would be used. In the four cases the soft water system included outlets in bath room, kitchen and laundry and the soft water was freely used.

The table below shows the results which were obtained. The time given includes only the days each water system was in actual use.

TABLE 7.

ENERGY CONSUMPTION DATA

Meter	Time Days	Energy Kw.-hr.	No. of People	Kw.-hr. per Month	Kw.-hrs. per Person per Month
A	47	1.30	3	0.83	0.276
B	35	0.50	2	0.43	0.215
C	30	2.25	3	2.25	0.750
D	42	4.50	6	3.20	0.533

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Assuming a unit cost of 10 cents per kw.-hr. it will be seen that the maximum cost for soft water pumping in the cases given is 7.5 cents, while the average is approximately 4.5 cents per person per month. It should be understood however, that this is a special and limited requirement where the amount of water consumed is small. For the general requirements of village or farm homes, especially where stock watering and lawn sprinkling facilities are to be provided the cost will be much greater.

Tests. Tests made on several suction lift, compression tank outfits with capacities of 100 to 300 gallons per hour showed overall efficiencies (ratio between output of pump and input to motor) varying between 10 per cent and 35 per cent, the average at 40 lb. tank pressure and 20 ft. lift being about 23 per cent. These tests were run against higher heads, however, than would ordinarily be used in service and the efficiency grows less as the pressure head diminishes. This being the case it seems reasonable to expect that under ordinary service conditions 20 per cent would represent a fair average efficiency. At this efficiency about 1.57 kw.-hr. is required to raise 1000 gallons of water 100 feet or force it against an equivalent pressure head. This corresponds to a condition of 40 pounds per sq. in. pressure in the tank and a suction lift of 7 1/2 feet or its equivalent.

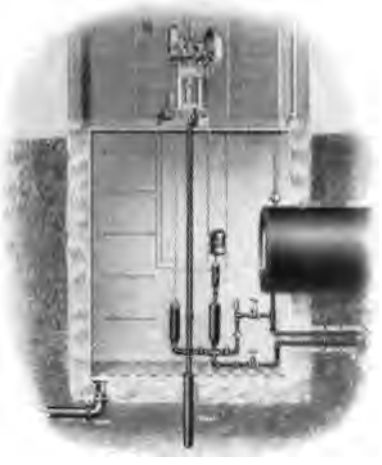


Fig. 6. Frost Proof Installation of a Deep Well System. (Courtesy of Ft. Wayne Eng'g & Mfg. Co., Ft. Wayne, Ind.)

If electric energy costs 15 cents per kw.-hr. then the expense of pumping 1000 gallons of water under average conditions will be $1.57 \times 0.15 = 23\ 1/2$ cents

Since 1000 gallons per day seems sufficient to supply the needs of a fair sized farm home (see page 17) it would appear that an expenditure of 20 to 25 cents per day might be considered as

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sufficient to cover the requirements of the average farmer, assuming cost of electricity as given above which may be taken as a representative figure where power is obtained from a transmission line. Where power is obtained from a farm lighting plant, however, its cost is likely to be higher as very few farm lighting plants produce electric energy at a total cost as low as 15 cents per kilowatt hour.

The following tables (Tables 8 to 14 inc.) present test data on several typical residence pumping outfits. The tests were made in the Purdue University Laboratories.

TABLE 8

TEST DATA ON SYSTEM No. 1

Pump Capacity—100 Gallons per Hour
Motor—⅓ Hp.,—Alternating Current, 60 Cycle.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
50	5	106.8	3.0	195	287	66.75	137.0
40	5	106.7	2.9	182	292	66.5	114.1
30	5	106.8	3.1	180	293	67	91.1
20	5	107.4	2.9	164	297	70.7	68.2
10	5	106.9	2.8	149	298	74	44.6

9 Input Kw.-hr.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal 100 Ft. Head
.164	.0413	.0034	21.1	96.1	489	2.04	1.49
.152	.0345	.0028	19.1	96.1	536	1.87	1.64
.150	.0275	.0022	15.3	96.5	535	1.87	2.05
.137	.0225	.0018	13.7	101.7	618	1.62	2.37
.124	.0149	.0012	10.2	106.5	715	1.40	3.14

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TABLE 9.

TEST DATA ON SYSTEM NO. 2

Pump Capacity—180 Gallon per Hour.
Motor—⅛ Hp, Alternating Current, 60 Cycle.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
50	8	109	4.2	260	254	192	140.5
40	8	109	4.1	246	256	196	117.6
30	8	109	3.9	211	261	198	95.3
20	8	109	3.7	264	264	198	73.4
10	8	109	3.7	176	266	197	50.7

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.260	.0762	.0102	28.3	172.5	641	1.56	1.11
.246	.0654	.0087	26.7	176.8	724	1.38	1.17
.211	.0534	.0071	24.5	177.8	820	1.22	1.28
.264	.0412	.0055	20.2	177.8	872	1.14	1.56
.176	.0283	.0037	15.8	177.0	992	1.01	1.99

TABLE 10.

TEST DATA ON SYSTEM NO. 3

Pump Capacity—270 Gallon per Hour.
Motor—¼ Hp., Direct Current, 32 Volt.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
50	6	32	10.3	----------	119	219	144.0
40	6	32	9.0	----------	120	223	121.6
30	6	32	7.8	----------	126	224	98.6
20	6	32	6.8	----------	128	223	75.7
10	6	32	5.8	----------	132	221	52.9

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.332	.1193	.0119	35.9	262.5	790	1.26	.87
.288	.1023	.0102	35.5	267.0	927	1.07	.88
.250	.0833	.0083	33.3	268.0	1072	.93	.94
.217	.0637	.0064	29.3	267.0	1228	.81	1.07
.187	.0442	.0044	23.5	265.5	1416	.70	1.33

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TABLE 11.

TEST DATA ON SYSTEM NO. 4

Pump Capacity—140 Gallon per Hour.
Motor—¼ Hp., Alternating Current, 60 Cycles.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
40	10	110	4.9	303.5	548	186	113.4
30	10	110	4.7	273.0	553	189	91.0
20	10	110	4.6	215.5	556	193	68.3
10	10	110	4.7	260	563	196	44.9

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.303	.0516	.0086	17.0	133	440	2.10	1.85
.273	.0385	.0064	14.2	135	496	2.01	2.21
.265	.0294	.0049	11.1	138	522	1.91	2.8
.260	.0199	.0033	7.6	141	542	1.84	4.1

TABLE 12.

TEST DATA ON SYSTEM NO. 5

Pump Capacity—300 Gallons per Hour.
Motor—¼ Hp., Direct Current, 32 Volt.

1 Gage Pressure Lb. per Sq.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
35	5	32	10.2	---	2020	19	84.7
30	10	32	9.8	---	2080	105	74.1
25	5	32	9.2	---	2140	81	63.2
20	10	32	8.5	---	2210	224	33.9
15	5	32	7.7	---	2300	147	44.1
10	5	32	7.1	---	---	204	36.4

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.328	.0073	.0006	2.2	27.4	83	12.04	14.12
.314	.0177	.0029	5.6	75.5	240	4.16	5.61
.295	.0234	.0019	7.9	117.2	397	2.52	3.99
.274	.0274	.0046	10.0	161.0	590	1.69	3.14
.246	.0295	.0024	12.0	210.5	855	1.17	2.65
.227	.0337	.0028	14.8	294.0	1295	.77	2.12

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TABLE 13.

TEST DATA ON SYSTEM NO. 6

Pump Capacity—160 Gallons per Hour
Motor—⅛ Hp., Direct Current, 32 Volt.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
50	10	32	5.6	.....	162	200	138.7
40	10	32	5.3	.....	167	202	115.2
30	10	32	4.7	.....	170	212	91.8
20	10	32	4.3	.....	175	223	69.3
10	10	32	3.7	.....	179	230	46.4

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.181	.0627	.0146	34.8	144.0	795	1.25	.90
.171	.0527	.0087	31.0	145.0	848	1.17	1.02
.153	.0440	.0073	28.8	152.6	998	1.00	1.08
.138	.0349	.0058	25.3	160.0	1155	.86	1.25
.121	.0236	.0039	19.1	165.2	1365	.73	1.58

TABLE 14.

TEST DATA ON SYSTEM NO. 7

Pump Capacity—180 Gallons per Hour.
Motor—½ Hp. Direct Current, 32 Volt.

1 Gage Pressure Lb. per Sq. In.	2 Time Min.	3 Line Volts	4 Line Amp.	5 Line Watts	6 Pump Speed R.P.M.	7 Weight Water Lb.	8 Total Head Feet
50	6	31.4	14.8	.....	320	139	154.9
40	7	31.4	14.2	.....	325	163	132.0
30	7	31.4	13.6	.....	328	167	109.0
20	6	31.4	12.9	.....	334	146	86.0
10	6	31.4	12.4	.....	339	148	63.0

9 Input Kw.	10 Output Kw.	11 Output Kw.-hr.	12 Eff. Percent	13 Gal. per Hr.	14 Gal. per Kw.-hr.	15 Kw.-hr. per 1000 Gal.	16 Kw.-hr. per 1000 Gal. 100 Ft. Head
.466	.0808	.0080	17.3	166.5	356	2.80	1.81
.447	.0694	.0081	15.5	167.2	374	2.68	2.02
.427	.0587	.0068	13.7	171.5	400	2.48	2.28
.407	.0473	.0047	11.6	175.0	430	2.32	2.70
.391	.0352	.0035	8.9	177.5	454	2.20	3.50

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LIST OF PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE

BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright, 1922.

CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

BULLETIN No. 2. House Construction that Reduces Heating Costs, by James D. Hoffman, 1923.

BULLETIN No. 3. Pictorial Description of Engineering Activities, Purdue University, 1923.

The following material has been issued in mimeograph form.

FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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BULLETIN OF
PURDUE UNIVERSITY
PUBLICATIONS OF THE ENGINEERING DEPARTMENTS

VOL. VIII MARCH, 1924 NO. 5

Proceedings
Tenth Annual Road School

Held at

PURDUE UNIVERSITY

Edited by

BEN H. PETTY

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ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

Published by Purdue University at LaFayette, Indiana

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Purdue University recognizes its opportunity for public service by carrying the benefits of its teaching and research activities to those in the State who are interested in engineering problems, but who are unable to be benefited by the regular courses of resident instruction which are offered at the University.

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BULLETIN NO. 5
ENGINEERING EXTENSION SERVICE

PROCEEDINGS

OF THE

TENTH ANNUAL ROAD SCHOOL

HELD AT

PURDUE UNIVERSITY

JANUARY 7 TO 11, 1924

Under the Direction of
The School of Civil Engineering
With the Co-operation of
The Indiana State Highway Commission,
The Indiana County Highway Superintendents' Association,
The Indiana County Surveyors' and County Engineers' Association,
and
The City Street Commissioners' Association
of the State of Indiana.

Compiled and edited by Ben H. Petty,
Assistant Professor of Highway Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
MARCH, 1924

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PREFACE.

The purpose of the annual Purdue Road School is to bring together engineers, officials, contractors and citizens of the State who are interested in street and highway problems, to the end that they may not only hear various phases of these problems presented by experts of national reputation, but also that they might have opportunity to meet and exchange ideas and experiences with each other. The design of pavements, construction methods, maintenance operations and traffic requirements are continually changing and no interested official, engineer or contractor can expect to keep in touch with these ideas without taking advantage of such agencies as the Purdue Road School.

The first school was held in 1915, with an attendance of 75. Since then there has been an increasing interest, the attendance reaching a maximum of 365 in 1922. The following table shows the classified attendance during the week of January 7 to 11, 1924:

State Officials	1
State Highway Commission	47
County Highway Superintendents	71
Assistant County Highway Superintendents	25
County Surveyors and Engineers	30*
City Street Commissioners	8
County Commissioners	7
Engineers and other Officials	5
Contractors	25
Material and Equipment Men	65
Miscellaneous	22
Total	304
Indiana counties represented	83
States represented	7

In 1921 a law was created by the state legislature which provides that all County Highway Superintendents shall attend the road school each year for a period of at least one week, with all expenses paid by the respective counties. A similar bill is now being fostered by the County Surveyors and County Engineers' Association. Undoubtedly increased efficiency of these various highway officials resulting from knowledge gained at this annual road school is of great value to the tax payers of Indiana.

*In two counties the offices of Highway Superintendent and Surveyor are combined, therefore these men are listed twice in the table, but only counted once in the total.

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A very enjoyable feature of the week was the annual banquet on Thursday evening. State Senator James H. MacDonald of Connecticut, who has served his State as Highway Commissioner for eighteen years, delivered the principal address, proving himself to be an orator and a very clear thinker on the highway problems confronting us. Credit for the success of the banquet is due Mr. E. H. O'Neill of Crawfordsville, who had charge of the arrangements.

Prof. C. C. Albright was in direct charge of the school. Assisting him on the program committee were: Mr. John J. Griffith, Mr. F. W. Connell and Prof. Ben H. Petty. The cooperation and counsel of Dean A. A. Potter, Dr. W. K. Hatt, Prof. W. A. Knapp and State Highway Officials contributed to the success of the school.

The annual road school is one of the activities of the Engineering Extension Service of Purdue University.

The papers, as printed in this volume, have been considerably condensed from the original form in which they were presented at the Road School due to the fact that the funds available for publishing the proceedings were limited. The Editor has endeavored also to eliminate repetition where the speakers discussed similar subjects.

Lafayette, Indiana. B. H. P.
March 10, 1924.

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PROGRAM

MONDAY, JANUARY 7, 1924.

Morning

Registration at Civil Engineering Building.

Afternoon

Presiding, Professor C. C. Albright.

Addresses of Welcome—

Doctor E. C. Elliott, President, Purdue University.

Doctor W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Replies—

Mr. A. P. Jones, President, Indiana County Highway Superintendents' Association.

Mr. D. L. Heaton, President, Indiana County Surveyors' and County Engineers' Association.

Mr. A. A. Girton, President, The City Street Commissioners' Association of the State of Indiana.

General Announcements—

Professor C. C. Albright.

The Present and Future Indiana State Highway System—

Mr. Earl Crawford, Commissioner, Indiana State Highway Commission.

TUESDAY, JANUARY 8, 1924.

Morning

Presiding, Mr. A. P. Jones.

Drainage of Roads—

Mr. Don Heaton, Engineer, Benton County.

Signs, Guard Fences and Railroad Crossings—

Mr. James L. Tucker, Clay County Highway Superintendent.

Construction and Maintenance of Small Bridges and Culverts—

Mr. Wm. J. Titus, Bridge Engineer, Indiana State Highway Commission.

Discussion—

Mr. George Dix, Clark County Highway Superintendent.

Mr. U. P. Anderson, Washington County Highway Superintendent.

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Afternoon

Presiding, Mr. A. H. Hinkle.

Development of Highway Surfaces—

Mr. C. M. Upham, Chief Engineer, North Carolina Highway Commission.

Construction of Bituminous Macadam Roads—

Mr. Orin M. Darling, Engineer, Allen County.

Records and Accounts of County Officials—

Mr. Lawrence W. Orr, State Examiner, Indiana State Board of Accounts.

Discussion—

Mr. Clyde Piper, Fayette County Highway Superintendent.
Mr. Elmer Blue, Putnam County Highway Superintendent.

WEDNESDAY, JANUARY 9, 1924.

Morning

Presiding, Mr. Don Heaton.

Specifications—

Professor Ben H. Petty, Asst. Prof. of Highway Engineering, Purdue University.

Reconstruction of State Roads with Bituminous Surfaces—

Mr. W. K. O'Neill, District Engineer, Indiana State Highway Commission.

Bituminous Road Maintenance—

Mr. Wm. G. Tonkel, Allen County Highway Superintendent.
Mr. Joseph Crowe, Porter County Highway Superintendent.
Mr. Matt Foster, Vanderburg County Highway Superintendent.

Specifications and Tests for Bituminous Road Materials—

Mr. Fred Kellam, Testing Engineer, Indiana State Highway Commission.

Discussion—

Professor R. B. Crepps, Testing Materials Laboratory, Purdue University.

Afternoon

Presiding, Professor Ben H. Petty.

Repair and Maintenance of Streets with Bituminous Materials—

Mr. D. B. Davis, City Engineer, Richmond, Indiana.

Discussion—

Professor C. C. Albright, In Charge of Highway Engineering, Purdue University.

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New Developments in Road Maintenance—

Mr. A. H. Hinkle, Superintendent of Maintenance, Indiana State Highway Commission.

Safety and Utility Factors at Railroad Crossings of Roads and Streets—

Mr. L. F. Shedd, Superintendent of Safety, C. R. I. & P. R. R. Co.

Materials for Road Maintenance—

Mr. A. J. Ryan, Decatur County Highway Superintendent.
Mr. Robert Crane, Daviess County Highway Superintendent.
Mr. Wm. S. Parks, Jasper County Highway Superintendent.

THURSDAY, JANUARY 10, 1924.

Morning

Presiding, Mr. A. A. Girton.

Construction of Gravel Roads—

Mr. Alvin E. Gempler, Engineer, Posey County.

Gravel Road Maintenance—

Mr. Jacob Girton, Shelby County Highway Superintendent.
Mr. Daulton Martin, Parke County Highway Superintendent.

Construction of Macadam Roads—

Mr. Homer Teeters, Engineer, Jay County.

Macadam Road Maintenance—

Mr. W. O. Jones, Wayne County Highway Superintendent.

Road Maintenance Machinery and Equipment—

Mr. W. O. Daugherty, Gibson County Highway Superintendent.
Mr. Charles Bryner, Elkhart County Highway Superintendent.

Afternoon

Presiding, Professor C. C. Albright.

Economy to the Public of Good Highway Maintenance—

Mr. S. C. Hadden, Editor, Municipal and County Engineering.

Relation of Cost of Roads to the Traffic—

Professor T. R. Agg, Professor of Highway Engineering, Iowa State College.

Construction of Concrete Roads—

Mr. C. C. Mason, Assistant Engineer, Marion County.

Concrete Road Maintenance—

Mr. A. P. Jones, Madison County Highway Superintendent.

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Evening

Annual Banquet.

Presiding, Professor C. C. Albright,
Home Economics Building,
Purdue University.

Address—

Mr. J. H. MacDonald, State Senator, Connecticut.

Annual Meetings

Indiana County Highway Superintendents' Association.
Indiana County Surveyors' and County Engineers' Association.
The City Street Commissioners' Association of the State of Indiana.

FRIDAY, JANUARY 11, 1924.

Morning

Presiding, Professor C. C. Albright.

Construction of Brick Roads—

Mr. E. C. Minton, Engineer, Tippecanoe County.

Brick Road Maintenance—

Professor C. C. Albright, Purdue University.

Mr. W. E. Gove, Tippecanoe County Highway Superintendent.

Road School Picture.

Highway Maintenance from the Standpoint of Service, Safety and Economy—

Mr. G. C. Dillman, Deputy Commissioner and Chief Engineer, Michigan State Highway Department.

Afternoon

Presiding, Professor Ben H. Petty.

Forecasting Highway Traffic—

Doctor W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Changes and Improvements in Design and Construction of Indiana State Roads—

Mr. J. T. Hallett, Road Engineer, Indiana State Highway Commission.

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THE MAINTENANCE AND REPAIR OF STREETS WITH BITUMINOUS MATERIALS.

By D. B. Davis,
City Engineer, Richmond, Ind.

The causes which tend to destroy the smoothness of a pavement within a city are somewhat different from those outside. In the city, we have in addition to the natural causes of failure, the voluntary action of the public utilities and contractors, wherein they must from necessity excavate in the city pavements in order to give to the people the service which they sell. The regulation of openings and replacements in city pavements is as vital a subject as the city official in charge has to contend with to keep his pavements smooth.

It may not be out of place briefly to describe the methods used in Richmond in this connection. Six years ago we did not have any effective regulation of openings and replacements of pavements. On every street there were trenches which had sunk all the way from two to six inches. From time to time lists were made of these sunken trenches and were referred to the various parties responsible. In most cases it was weeks and months before any real effort was made to fill them. In many instances the responsibility of the trench was denied.

The matter was taken in hand, investigation was made of the practice in other cities and an ordinance was drawn and passed by the city council. At this same time a system of patrol maintenance was inaugurated by the city. The ordinance provided that before a permit was granted to dig in any street, a deposit was necessary to cover the cost of backfilling and the replacement of the pavement over the trench. The city then took over this work of back-filling and pavement replacement and did it at actual cost plus 12 per cent for any future maintenance. This actual cost was deducted from the deposit made and the difference, if any, was refunded.

This placed every trench in charge of the city. If the trench was not kept in repair every one knew that the city itself was not doing its work. This system is still in force and no doubt is responsible for the easy way in which we can control the street maintenance.

Our system of patrol maintenance includes the use of a team which hauls a special wagon containing stone and sand with the necessary tools. Attached to the rear is a tar heating kettle. This wagon was especially constructed for this work, the running gears being from a discarded horse-drawn hook and ladder

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fire wagon. The sand compartment holds 30 cubic feet and the stone compartment holds 25 cubic feet. The amount of material carried on the wagon will supply stone and sand enough for pouring two barrels of Tarvia X, which is heated in the kettle at the rear. The kettle has a warming rack which holds an extra barrel covered with a tight hood. The materials thus carried will supply material for the gang for one half day without returning to the store-house.

The program outlined for this repair gang is to start at one end of town, patroling each street and patching all depressions, until the other end of town is reached, then they begin all over again. Only pavements of concrete, water bound and bituminous macadam and surface treated gravel are repaired by this outfit.

In repairing the depressions in these pavements, we first thoroughly clean all dirt and foreign matter from the depression with a shovel and wire broom, giving it a final sweeping with an old house broom. For the shallower holes or ruts, a little hot Tarvia X is poured over the surface, then a heavy coating of coarse sand is spread over the Tarvia while it is still hot. The deeper holes are filled to within ¼ inch of the surface with ¾ inch clean stone chips, smoothed off and tamped. Then hot Tarvia X is poured over and around them. About one and one-half gallons of Tarvia X is used per square yard of patch. Coarse sand is spread over the patch to give it a final finish and make it possible for traffic to go upon it immediately.

The larger cracks and depressions in concrete pavements are repaired in a similar manner to that described above for macadam and gravel pavements while the smaller cracks are repaired by merely pouring them full of the hot Tarvia.

A program is mapped out each year for the surface treating of various macadam and gravel streets in the city. A study of the condition of each city block is made by personal observation. A city map is then procured and the streets which inspection shows to be in greater need of a surface treatment are blocked off. Similar maps are kept each year showing in colors the various streets which have received surface treatments. By this method and record, the amounts of bituminous material per square yard are approximately determined and with the square yards in each city block known, this being kept in a card index, the total amount in gallons for each particular street is determined and set down. Each year the city council appropriates a certain sum of money for the maintenance of these streets and the work contemplated is kept within the budget. In 1923 about 250,000 square yards of pavement were surface treated.

The surface treatment of macadam is very well known although we find that due care should be exercised in getting the

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surface thoroughly cleaned, especially near the edge of the gutter where dirt is more liable to lodge and cake. We endeavor to use care in applying the amount of bituminous material that our experience has taught us is proper. Where, in our judgment, one-fifth of a gallon per square yard is sufficient, we endeavor to apply that amount and no more. We have found that it is better practice to apply thin coats instead of trying to build up a heavy mat which is liable to wave under traffic.

The prime purpose of our surface treatments is not, as many imagine, to lay the dust, but to waterproof and seal the surface to prevent dust.

We have, in the past, been able to select the streets which need surface treatments on their merits and not because some resident along the street thought it needed one. As long as this work is left to engineering experience and not political pressure it will function properly and economically, and no longer.

After the bituminous material is applied a covering is immediately spread theron. We use both pea gravel and stone chips for covering. We find, however, that the stone chips ranging from ½ inch to ⅛ inch with no dust, are inclined to hold their place a little more readily after traffic is turned onto the street. The flat sides of the stone present additional surface to adhere to the Tarvia.

The surface treatment of gravel streets which have previously been surface treated is similar in every respect to that of macadam. However the surface treatment of gravel pavements which have never been previously surface treated involves a few features which distinguish it from the other. For successful results with this type it has been our experience that the gravel surface must be firm and comparatively smooth prior to the application of the surface treatment.

The preparation of the surface consists in repairing all depressions by filling the same with ¾ inch clean stone chips tamped to about ¼ inch below the street surface and sealing them with hot Tarvia X. If there is dust on the surface, it can be removed to the gutter with a rotary sweeper. Otherwise good results have been obtained by applying the bituminous material directly to the gravel.

The Tarvia B is applied cold by means of a pressure distributor. For the initial treatment, one-third to one-fourth gallon per square yard is used, with subsequent treatments of one-third to one-fourth gallons per square yard. Better results are obtained by not applying any covering material whatever on the initial treament. This allows the bituminous material to be absorbed by the surfacing gravel to the extent that after traffic has ironed it out for a time, investigation shows that a crust has been

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formed of a thickness of from ⅜ to ½ inch. Subsequent treatments are covered with a light sprinkling of either pea gravel or stone chips to the amount of about 5 pounds per square yard.

It has been found that after traffic has used the treated gravel for some months, a few depressions may develop, due either to an excess of dust or a damp clayey spot on the surface at the time of application of the binder. These other places will require looking after. This work is taken care of by the maintenance patrol gang previously described.

We have made it a point to keep the surface treated gravel streets in good repair. This makes the fifth year that we have experimented with Tarvia B on gravel streets and have secured from that experience a good idea of the maintenance required to keep them in repair.

Our five years' experience with surface treated gravel has taught us to observe the following points:

Never apply the bituminous material on a gravel surface which is damp or excessively dusty, as it will not incorporate itself with the pavement and will soon break out.

Be sure to apply the treatment uniformly the full width of the street, otherwise it will ravel at the edges.

Have the surface firm and smooth before applying the binder.

Never apply the binder on any street which has not an adequate foundation, as the binder will not furnish that.

Do not apply the binder on any gravel street unless the treatments will be kept up when they are needed. It has been found that ½ gallon per square yard the first year with ¼ gallon per square yard the second year will keep the surface in such shape that no treatments will be necessary for two years. This applies to a residence street only. To put one treatment on a gravel street and then leave it alone will make it worse than if no treatment had been applied.

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THE RECONSTRUCTION OF STATE ROADS WITH BITUMINOUS SURFACES.

By W. K. O'Neill,
District Engineer, Indiana State Highway Commission.

The reconstruction of some of our state highways with bituminous surfaces has entailed the practical reconstruction of the road, including the rebuilding or lengthening of bridges and culverts, widening the roadbed and surface, the easing of curves and grades, and the re-surfacing with water-bound macadam preparatory to the application of a surface treatment, or a bituminous macadam surface.

When we found that the road was wide enough to accommodate traffic, that the bridges and culverts were in good condition and of sufficient width, that the foundation and surface were standing up under heavy loads at all seasons, and that there were no prohibitive grades; we repaired the depressions and irregularities by cold mix patches and paint patches and gave it a surface treatment.

The enormous increase in traffic, and especially truck traffic, has placed upon the roads a burden so much greater than was contemplated when they were built, that the foundation is not of sufficient strength even where the surface is properly maintained. I have in mind one particular section of road in southern Indiana which had been for years a toll road. It serves a number of towns in a length of 40 miles which have no railroad or interurban facilities, and as a result all freight and passenger traffic is concentrated on this highway. It was well located and built, but in spite of maintenance had been slowly breaking down under the increased traffic. For one year we tried to maintain it as a macadam road by applying stone and dragging. We succeeded in bringing the surface back to where it was smooth and fast, but at a cost for maintenance of about $1000.00 per mile per year.

During 1920 we applied a first aid treatment to the foundation. We sledged large stone into the places where the road had completely failed and then applied smaller stone and dragged. When we began our construction in 1921 we were pretty well satisfied that the foundation was heavy enough.

The work consisted of the construction of an 18 foot water-bound macadam surface which we intended to maintain as a surface treated type. It was done entirely by our own forces under the supervision of our local superintendent. The stone was crushed at a local plant two miles from the job and was hauled by truck. We specified No. 1 stone (3½" to 2½") for

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the base course, and No. 2 stone (2½" to 1½") for the wearing course.

Owing to the fact that we could find no suitable detour, this work was done under traffic. This multiplied our troubles and increased the expense, besides making it very difficult to obtain the smooth surface we desired. Our experience has shown that all traffic should be kept off the road when any water-bound construction is going on. It is almost impossible to avoid irregularities in the surface if traffic is allowed to rut the large stone after it has been rolled. Small depressions, say 18 to 24 inches long, are not so serious since they are not objectionable to the occupants of a car traveling at the average speed. However, the longer depressions from 6 to 10 feet, are very noticeable. Again the smaller depressions can be eliminated by paint patches and successive surface treatments, while the longer waves require a lot of careful patching to bring about a smooth surface.

The length of time that must be allowed between the completion of the wearing course and the first surface treatment depends upon a number of factors. If made of very hard, poor cementing stone, traffic will blow off the screenings in a much shorter time than if made from a comparatively soft stone of a high cementing value. Light, high speed traffic will suck the screenings from between the large stone more quickly than slow moving trucks. The work I have in mind was completed in October and was surface treated the following July. It was built of a hard stone of poor cementing value and as a result it was necessary to spread screenings on the surface during the fall and winter to prevent possible raveling of the surface. We have surface treated some water-bound patches a week after they were completed.

A surface is ready for treatment when it has a pitted appearance and the sharp angles of the stone are exposed. If you cannot bring about this condition by exposure to traffic, and sweeping and cleaning the surface, the treatment had better be omitted to avoid wasting money. In any case, no matter how long the surface has been exposed to traffic, it should be gone over with a mechanical sweeper, brooms and shovels to remove mud and other foreign material, especially along the edges of the metal.

The first treatment was applied at the rate of 0.4 of a gallon per square yard in two courses of 0.2 gallon each. To avoid traffic interference as much as possible, one half the road surface was treated at a time. As the weather was very warm, no chips were spread on the first application in order to secure as complete an absorption of bitumen by the road surface as possible. The second application was covered with stone chips, size ¾" to ¼", at the rate of 12½ pounds per square yard. These chips

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had been placed along the road in piles of about ¼ cu. yard. each. The bituminous material, which met our specification for Tar T. M., was applied by means of a pressure distributor at a temperature of 140 degrees F.

The next year this section of road was given another treatment at the rate of 0.3 gallon per square yard, put on in two applications. Since this was a second treatment, just enough chips were spread on the first application to absorb the excess bitumen. A common fault with some surface treatments is a too liberal use of covering material. It is always possible to add chips when the surface begins to bleed; but it is impossible to take away the excess chips when the surface begins to lose its life and disintegrate.

Last year we let a contract for the construction of eight miles of bituminous macadam construction. The mainteance forces undertook to rebuild the eight miles preparatory to the construction of the wearing course. This involved extending a number of small pipe and box culverts, the construction of two slab top culverts and some short retaining walls. In addition, the bridge department rebuilt three pony trusses whose length totaled 164 feet. The roadbed was widened to 28 feet, some of it through heavy rock cuts and on high fills. Sharp curves were eased off, and irregularities in grades were eliminated by building up the low spots with heavy stone and replacing the bumps at changes of grade with vertical curves.

The first three miles of this road is hill-side location, with a maximum grade of 6½% and an average of 5%. In order to eliminate the excessive crown, (which was good practice on heavy grades with the old type of road), and to obtain the necessary super-elevation on curves; the roadbed and base course were built up as much as 3 feet at some points.

Our specifications for the wearing course called for a width of 18 feet and a crown of 2″ except on curves and grades. As we approached curves we raised the outside half of the roadway until the necessary super-elevation was obtained. Beginning with a 2″ crown on flat or very light grades, we decreased the crown in proportion to the increase in the rate of grade until on a 5% grade we had a flat section.

The work was carried on under the supervision of our local Superintendent and an Engineer-Inspector. They directed the work of a grade foreman, a bridge foreman, a foreman in charge of the construction of the base course, and a truck foreman responsible for the delivery of stone to the contractor by our own trucks. In addition to the above, we had a light grading crew that built the earth shoulders.

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Our equipment for heavy grading consisted of a Holt 10 ton caterpillar tractor, an Adams 12 foot Road King grader, slip and wheel scrapers, road plows and necessary small tools. We also organized a rock drilling gang and rented a portable compressor and jack hammer. The stone blasted out of rock cuts was placed under the base course where it was necessary to raise the elevation of the road, or where a change of location made a heavy foundation necessary.

Our equipment for building the base course consisted of two Acme gasoline rollers, two 600-gallon water tanks mounted on Quad trucks, a road harrow, a small grader, form boards, stone rakes and other small tools. One piece of equipment, which we insisted on the foreman using, was an 18 foot combination straight edge and template. We were trying to get a smooth surface, true and uniform as to grade and crown, and tried particularly to avoid a wavy surface.

We let contracts for stone to be crushed at two plants located along the road. The work of building up the base course was expected to take between 9,000 and 10,000 cu. yds., in addition to the amount called for in the wearing course. We used from 14 to 18 trucks hauling stone to our forces and to the contractor. These trucks were under the supervision of a truck foreman, whose duty it was to give each truck a daily inspection, and to dispatch trucks from both plants to deliver stone as it was needed at the various points.

The base course was built of No. 1 stone (3½" to 2½"), No. 2 stone (2½" to 1½"), and screenings. We used the No. 1 size along the edges where the high crown on the old road made a heavy patch necessary. On the lighter patches and in the center of the road the smaller stone was used.

Our specifications for stone used in the top course called for the No. 1 size for coarse aggregate and size No. 3 (1½" to ¼") and size No. 4 (¾" to¼") for the coarse and fine covering respectively. The large stone was spread and raked to a depth of 4 inches for the full 18 feet, requiring 1,200 cu. yds. per mile. The covering material was hauled and dumped alongside the road in one yard piles ahead of the large stone, so that our trucks were kept off the large aggregate after it was spread. The keystone was delivered at the rate of 160 cu. yds. and the fine covering at 140 cu. yds. per mile.

To avoid waves and ruts in the surface, the contractor was required to harrow the large stone thoroughly before rolling. This also served to bring the larger stone to the surface. Earth shoulders had been built to a height of 4" above the top of the surface and the rolling was commenced with the outside drive wheel covering this shoulder and the metal, gradually working

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toward the center of the road. Any depressions which developed during the rolling were eliminated by loosening the stone and adding a small amount of new metal.

The amount of rolling needed to get the best results depends on the size and hardness of the stone. No specific rule can be given. Observation and experience are your only guide. However the rolling should be stopped before the voids are closed enough to prevent free and uniform penetration of the bituminous material.

The contractor used three 10 ton rollers. One roller was used to compact the stone ahead of the distributors. When a sufficient length for a days run for the distributors had been shaped up, it was brought back to assist the other two rollers which were kept continually rolling the treated top.

The bituminous material used on this work met our asphalt specification A-2. We specified an application of 2¾ gallons per square yard; 2 gallons on the first application and ¾ gallon on the second. The bituminous material was applied by means of a self propelled pressure distributor at a temperature of 340 degrees F. One half of the 18 foot width was treated at a time.

After the first application, just enough covering was applied to prevent the roller wheels from picking up the bitumen. The surface was then rolled until the voids were completely closed and the covering material incorporated with the bitumen. In extremely warm weather it may be well to allow the bituminous material to harden slightly before rolling. When the weather is cooler the rolling must be begun immediately to ensure the closing of all voids, and obtain a solid compact surface.

The remaining voids in the surface that were not closed by the rolling were then filled by brushing chips over the surface and going over them once with the roller.

The seal coat (¾ gal. per sq. yd.) was applied as soon as this rolling was finished. Care was taken to see that all loose stone, leaves and other foreign matter were cleaned off the surface. After this coat was applied the surface was covered with No. 4 chips at the rate of one cubic yard to each 75 square yards of surface and thoroughly rolled.

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BITUMINOUS ROAD MAINTENANCE.

By Wm. G. Tonkel,
Allen County Highway Superintendent.

Bituminous maintenance and construction meant nothing to me a few years back, for I was not sold on the idea of a bituminous macadam road and could not speak favorably of it. However, after inspecting roads in the northern part of Ohio, noting the condition and abundance of this type of construction and after giving it a great deal of thought and study I came to the following conclusions:

1st. That a bituminous type of road was a success.

2nd. That in order to be a success the initial construction should be done by capable, experienced contractors.

3rd. That in order to insure the proper smoothness and binding qualities a carpet coating should be put on the next year after construction.

4th. That the cost including maintenance of this type of highway was considerably less than I had thought.

To fully explain these conclusions I will say that bituminous roads are a success, for in this tour we traveled miles and miles without getting off this type of road construction, each road being level and smooth. Evidence of its success was that more construction of this type was being petitioned in that locality, for surely nothing is a success until it has public opinion behind it. When petitions are circulated for a road it means that public opinion is in favor of its construction and its worth.

It is necessary the next year after the job is completed to go along with a pressure tank and put on a coat of tar or asphalt and allow this to settle, say two or three hours, and then finally cover up lightly with stone chips or pea gravel.

One of the most important features of maintenance on any type of road is that of side-ditching and drainage. The side ditches on every road should be deep enough that at no time will the level of the water reach the bottom of the metal on the road.

Whenever holes appear on the road they should be carefully swept out, all the loose particles removed and the holes patched prior to the carpet coating. The traffic will then immediately iron out these patches and when the carpet coating is put on each particle of stone will be held firmly in place and become part of the compacted metal. None of this repair should be done when the road is wet for water does not mix well and serves as a resistance to the binding qualities of either tar or asphalt.

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The shoulders and berms should always be compact and conform to the crown and grade of the road so as to take the surface water off the highway as quickly as possible. They should be compact enough to serve as a curb to the edge of the pavement. A great deal of trouble has been experienced in what is known as ravelling on the sides of the highway. This can be eliminated by putting down a heavy base on both sides of the road and rolling into the berm coarse aggregate of stone.

Not every superintendent can qualify himself as a road superintendent by being just a democrat or republican. In order to improve himself for this position he should school himself to the requirments of his work, because I honestly believe that sooner or later road superintendents will be licensed and called upon to pass a regular examination. In maintaining county roads, a superintendent has in his power perhaps the greatest investment in his county. I don't believe you can show me where any one single institution in your county has the capitalization that the combined capitalization of the county roads would be. Therefore, why shouldn't the county demand even greater qualifications from its manager, i. e. the superintendent, than the private institution would demand of its general manager or general superintendent?

CONSTRUCTION OF BITUMINOUS MACADAM ROADS AND STREETS.

By ORIN M. DARLING,
Engineer, Allen County.

There are five distinct steps in the construction of the bituminous macadam surface, which substantially are as follows:

1st. A layer of coarse aggregate is spread upon the foundation. This coarse aggregate may consist of broken stone, mine tailings or slag, but preferably broken stone should be used. The stone must be clean and free from dust or an excess of flat or elongated pieces. It should have a percent of wear of not less than six (6). When tested by means of laboratory screens, it should be uniformly graded between the following limits: passing two and one-half (2½) inch screen 95 to 100%, passing one and one-quarter (1¼) inch screen 0 to 15%. This layer of crushed stone should have a thickness of 2½ inches after rolling.

2nd. After the coarse aggregate has been spread to the required thickness, it should be dry rolled with a three wheeled roller weighing not less than 10 tons. The rolling should start longitudinally at the sides and proceed towards the center of the pavement, overlapping on successive trips by at least one-half

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the width of the roller. The rolling should be continued until the compacted coarse aggregate possesses a firm surface true to the specified grades and cross-sections and presents a texture which will allow uniform penetration of the bituminous material. If any irregularities appear during or after the rolling, they must be remedied by loosening the surface and removing or adding coarse aggregate, after which the area disturbed including surrounding surface must be rolled until satisfactorily compacted to a uniform surface. Care should be taken to prevent the earth berms from being mixed into this stone along the edge of the pavement and should earth or dirt get into this course before the bituminous material has been applied, the dirty stone should immediately be removed and replaced as described before. As much mechanical bond should be given this course as is possible by rolling without grinding up the stone.

3rd. The first application of bituminous material should then be made by means of a motor pressure distributor. This application may be made with hand pouring pots but more satisfactory results can be obtained by a pressure distributor. The air temperature in the shade should not be less than 50 deg. F. The stone should be absolutely dry for its entire depth. The nozzels on the spraying apparatus should be perfectly clean. The bituminous material, if a tar product, should be heated to approximately 250 deg. F.; if an asphalt, to approximately 350 deg. F. The heated bituminous material should then be evenly applied at the rate of one and one-half (1½) to one and three-quarter (1¾) gallons per square yard and at a uniform pressure of about 60 pounds per square inch. The contractor should provide all necessary facilities for determining the temperature of the bituminous material, both during the heating period and the period of application. A stationary thermometer and a pressure gauge should be located so as to be easily observed by the inspector while walking beside the distributor.

The pressure distributor should be so designed that the bituminous material will be applied uniformly to a normal width of not less than 6 feet, with provision for applying lesser widths when necessary. To prevent lapping at the end junction of two applications, the distributor should be carefully watched and shut off the moment the application begins to thin just before the tank becomes empty. Then before starting to apply a new load, a heavy tar paper should be spread over the newly treated portion of the road for a short distance back from the point where it is intended to start applying the new load so that the distributor will be going at full speed when it arrives at this point.

As soon as the bituminous material has been applied, the inspector should carefully inspect every foot of the surface to locate portions that have been missed, "fat spots," or points of

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improper penetration. The missed portions should be carefully covered with a pouring can. If fat spots or points of improper penetration appear, they should be picked loose, new stone applied, rerolled and treated again.

4th. The next step is the filling of the surface voids with intermediate aggregate. This should be applied and rolled in while the bituminous material is still warm. The intermediate aggregate or key stone should possess the same qualities as specified hertofore for the coarse aggregate and when tested by means of laboratory screens, it should be uniformly graded between the following limits: passing one and one-quarter (1¼) inch screen, 95 to 100%; passing a one (1) inch screen, 25 to 75%; passing a three-quarter (¾) inch screen, 0 to 15%. This aggregate should be perfectly dry when applied and should be evenly broadcast over the treated surtace in such quantities as to fill the surface voids and just cover the treated surface enough to permit rolling without "picking up." The surface should be thoroughly rolled and compacted. After the rolling is finished all loose, surplus material, which remains on the surface should be broomed off and the final or seal coat applied.

5th. The fifth step is the application of the seal coat, which is put on for the purpose of completely sealing the surface of the road. This second application of bituminous material is applied under the same conditions and in the same manner as the first application, except that the rate of application should be one-half (½) gallon to each square yard of surface. While the bituminous material is still hot, dry fine aggregate should be broadcast over the surface and rolled until it is thoroughly bonded to the road. Extra care should be taken in applying the fine aggregate to prevent it from bunching under the roller. Only enough to take up all excess bituminous material should be applied.

The fine aggregate for this course should meet the same requirements as set out heretofore for the other aggregate and when tested by means of laboratory screens should be uniformly graded between these limits: passing a three-quarter (¾) inch screen, 95 to 100%; passing a one-half (½) inch screen, 25 to 75%; passing a one-quarter (¼) inch screen, 0 to 15%.

The rolling of this course should be complete and thorough in every respect. Final rolling should be, if necessary, continued from day to day, the rolling being done during the period of the day when the temperature is highest, until the finished surface is uniform, free from ruts or irregularities in contour, and true to the established crown and grade.

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SPECIFICATIONS AND TESTS FOR BITUMINOUS ROAD MATERIALS.

Discussion by PROF. R. B. CREPPS,
In Charge of Testing Materials Laboratory,
Purdue University.

The tests and specifications for bituminous materials for various types of pavements are becoming standardized through efforts of: The American Society of Testing Materials, The American Society of Municipal Improvements, The Asphalt Association and various public service bodies. The number of tests are being reduced to a practical working basis and while certain state highway commissions still maintain varied exceptions to the proposed standard tests, most of these differences will soon be harmonized.

The tests commonly specified are: penetration, flash point, loss on heating, penetration of residue, ductility and percentage of bitumen soluble in carbon tetrachloride.

The penetration test is most important for consistency of asphalt in specifying the grade desired and controlling the manufacture.

A much neded simplification as regards asphalt, (effective Jan. 1, 1924), has been brought about through the efforts of Mr. Herbert Hoover, Secretary of Commerce, and the various organizations interested in its preparation and use. For paving purposes the penetration limits are reduced from 88 to 9 as follows:

	Penetration Limits		
Sheet Asphalt	25- 30	30- 40	40- 50
Asphaltic Concrete	50- 60	60- 70	85-100
Asphaltic Macadam and Surface Treatments	100-120	120-150	150-200

Joint fillers for various types of construction were reduced from 14 to 4 as follows:

	Penetration Limits		
For brick	35-50		
For admixtures of sand.....	50-60	60-70	85-100

The mid point is desired in each case with an allowable tolerance to either limit.

It is very important that correct sampling of materials be adhered to. Samples for testing should represent an average of the bulk. They should not be contaminated with dirt and should be properly marked for identification. A sample for laboratory tests should contain at least one quart of the bituminous material.

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CONSTRUCTION OF BRICK ROADS.

By E. C. MINTON,
Engineer, Tippecanoe County.

A desirable road is one that will remain in constant condition for satisfactory travel for a great many years; a road that will not need constant repairs, which can be really repaired and not patched; one that will be dustless, will not become wavy, and will not crack, yet flexlible enough to adjust itself to settlement of the subgrade and remain waterproof and practically skidproof.

Brick with plastic filler seems to fulfill these requirements. Not the brick road that is carelessly or ignorantly built; not the brick road that is built according to the whim of some inexperienced person, but the brick road that can be and is built according to the most improved methods affording a quality and service in keeping with the price paid for it.

About five years ago a committee was appointed by the Federal Highway Council to investigate and study natural influences involved in the subgrade and its relation to road surfacing and traffic. One of the principal discoveries resulting from the activities of this committee discloses the fact that subgrades of most soils throughout the country are subject to expansion and contraction due to the influence of water. The forces of expansion in the case of a saturated subgrade are of extraordinary power, often resulting in the destruction of rigid surfaces. As soon as this fact was established it became apparent that the practice of constructing a rigid slab was entirely wrong and so the design for the brick pavement was changed in order to counteract the destructive agencies discovered.

This type of brick wearing surface for roads and pavements is known as the vertical fiber brick pavement. The name is taken from the method in which the brick are laid in the pavement with the fiber or grain perpendicular to the road surface. These brick are wire-cut and the wire-cut surface is placed up in the pavement affording an excellent surface for the coating of asphalt.

In the construction of the vertical fiber brick pavement the old gravel or macadam road, after proper preparation, makes a good base. This kind of a base is not rigid and avoids the impairment of the pavement by contraction and expansion forces.

When it is necessary to remove practically all the metal on a roadway, in order to place the new surface to grade, it is customary to use cement concrete for base material. When such a base is to be placed for the fiber brick construction, engineers will find that a five (5) inch base is ample. The cushion course

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and asphalt filled brick afford ideal protection to the base from traffic impact.

Over-designing is as poor engineering as under-designing. The taxpayer is beginning to feel the cost of local improvements more than ever, and it is, therefore, necessary that every care be given to the design of the road to reduce the cost to as low a figure as is consistent with safety. Many miles of roads and many of the heavy traffic streets throughout the states west of the Mississippi River are paved with vertical fiber brick surfaces on four inch concrete bases and are giving satisfactory service.

Upon the base course a cushion is spread by means of a template. This cushion is of sand or sand-mastic, and should never be of a greater thickness than one (1) inch. This should be rolled with a small hand roller in order to obtain a uniformly compacted cushion. The mastic cushion consists of seven (7) to ten (10) per cent of refined tar or asphalt and sand. In resurfacing, where the paving block of greater depth would raise the surface of the finished pavement above the established grade, it is customary to use the smaller fiber block, two and one-half (2½) inches in thickness. These blocks, when embedded in the elastic cushion, will withstand the heaviest impact of traffic. After the cushion course is prepared, the vertical fiber pavers are laid in the usual manner and then rolled with a self-propelled roller weighing not over five (5) tons until the surface is smooth.

Immediately after the rolling the filler should be applied. It is very important that the filler be of the highest quality of special refined asphalt so that it will adhere firmly to the brick and will not become brittle under freezing temperature or become too soft or bleed in the summer. The filler should be poured on the pavement at a temperature of not less than three hundred (300) degrees Fahrenheit and squeeged in to the interstices, care being taken to completely fill the joints so that after cooling there will not be a settlement of over a quarter of an inch. No more asphalt should be left on the top of the brick than is necessary to completely cover the brick.

As soon as the asphalt is poured and cooled, so that there will be no more settling of the asphalt in the joints, a coating of fine sand should be spread over the pavement to a depth of about one-half (½) inch and rolled into the asphalt. A little excess sand should be left on top of the pavement for about ten days for the traffic to work in. As soon as the sand coating is rolled, the pavement may be opened to traffic. Compliance with these details will secure an ideal pavement.

There are many kinds of surfaces that can be constructed at a lower cost, but a good road at $40,000 a mile is far cheaper than a poor one at $20,000. The lower cost roads built a few years ago in many places are gone or requiring expensive repairs. We must build roads to hold up under traffic.

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BRICK ROAD MAINTENANCE.

By PROFESSOR C. C. ALBRIGHT,
In Charge of Highway Engineering, Purdue University.

In presenting a brief discussion of "Maintenance of Brick Pavements," I consider it desirable to first note the causes of failure. This may result from abrasion or wear of the surface due to the action of traffic; or it may occur from breaks or settlements because of inferior materials, poor foundation, improper design, or faulty workmanship.

Some of the very early pavements laid in this country were constructed of brick which were too soft to withstand the severe action of steel tires and metal shoes and as a result the surface eventually became so rough and disagreeable to traffic that, in many instances, it was torn up and a new one built. Pavements constructed in the last twenty-five years seldom require any extensive renewal or repair because of abrasion or inferior material, however, they do require maintenance because of foundation, design and workmanship troubles.

Defects are nearly always small at first but may rapidly increase in size if neglected. As soon as a fault appears the cause should be found and the proper remedy applied. Individual brick which have failed should be removed and replaced with good ones. Unless the failure is observed when it first occurs and the remedy applied, the adjacent surface will be affected requiring more extensive repairs. Therefore, in making a patch, the adjacent surface should be carefully examined for slightly worn brick. These should be turned over and relaid with the new ones, thus presenting a new and smooth surface to traffic.

Expansion joints should be kept full with the bituminous materials at all times so that the adjacent edges of the brick will be protected. They will require attention prior to cold weather as some of the expansion material will be squeezed out under hot summer conditions. An expansion joint is a point of weakness in the pavement and should be kept sealed to prevent the entrance of water to the base.

Where a sand cushion has been used, a settlement of the surface sometimes occurs. This may result from too little or no rolling of the sand, the sand flowing into a break in the base, or from water displacing the sand. The remedy consists in removing the brick over the depressed area, repairing the base if necessary, renewing the cushion and relaying the surface.

City pavements frequently suffer as a result of cuts made for gas, water or other public service connections. In making such

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a cut the brick should be carefully toothed out over a width greater than the desired width of cut. The base should then be cut through with vertical edges over a width also more than the earth trench. The trench is next made, the service connection installed and the trench back filled. In filling the trench the earth should be dampened if necessary and carefully tamped in layers not to exceed 6 inches deep. The base and top are then restored in order. The shoulders of subgrade and foundation respectively afford a safety factor against settlement of the base and top.

On old pavements where the filler has been partially removed by traffic and weather action, it may be restored and the pavement protected by an application of asphalt or tar. A low penetration material, either cut back or heated, should be used. It should be covered within a few minutes by a thin coating of clean, coarse sand. Traffic should be kept from the street for a few hours. If this is not possible one half of the street may be treated at one operation and the remainder completed next day.

Old surfaces that are badly cobbled and rough may be resurfaced with sheet asphalt, bituminous concrete, penetration macadam or rock asphalt. The surface should first be carefully cleaned by sweeping or flushing or both. Low spots may be filled to an approximate level with the general surface of the pavement with portland cement concrete or cold patch material. If cold patch material is used it should be tamped or rolled in place and carefully proportioned to avoid a too rich mixture. The entire surface of the street is then given a paint coat of tar or asphalt depending on the material to be used in the bituminous top. The binder or top may be applied when the paint coat no longer leaves a stain when the finger is pressed aganst it. The surfacing material should not be less than one inch in thickness over the high points. Two inches will be better if sheet, emulsified or rock asphalt is used, while a penetration top should be two and one-half to three inches in depth.

In closing, I may say that the fundamentals of economical maintenance are constant vigilance and immediate correction or repair of all faults appearing in the pavement.

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CONSTRUCTION AND MAINTENANCE OF SMALL BRIDGES AND CULVERTS.

By W. J. Titus,
Bridge Engineer, Indiana State Highway Commission.

Section No. 16 of the Indiana State Highway Commission law states that "all drains, culverts and bridges shall be considered as a part of a State highway." By including this section in its statutes, Indiana has taken a step forward in the effort to secure 100% efficient highways. In some states, the building and repair of bridges have not been the duty of the State Highway Commission until it is proposed to hard-surface the roads on which they are located, while in some other states, the bridges are not at any time under supervision of the State.

Most states are realizing the folly of a haphazard method of building and maintaining their bridges, especially those on the State highway systems, as it is evident that it is a great waste to spend huge sums on the highways and allow the bridges to shift for themselves. No highway is stronger than its weakest bridge. A secondary highway will carry an occasional heavy truck load without serious damage to the roadway surface, but a single heavy truck load may totally destroy a weak bridge, with great financial loss and sometimes loss of life.

Because they are the most permanent feature of modern highway construction with the possible exception of location and grade work, small bridges and culverts should be built for permanence and to withstand heavy truck usage of modern overland transportation. Bridges and culverts should be designed to stand 20 ton traffic because the truck business is general in Indiana, and for the second reason that many important county roads are designed later to be added to the state road system. Bridges and culverts properly constructed on country roads will not have to be strengthened, widened or rebuilt to handle the augmented traffic of state roads when they become a part of the state system, for they will be of identical utility of state built structures.

One of the big problems of state road construction is the thousands of small and weakly constructed bridges that are hazardous to increased traffic. Many were designed when roads were single track affairs, again many have foundations too weak for support of modern traffic. Under no condition should new bridges be less than 18 to 20 feet wide, and able to support 20 ton traffic. If this plan is adopted it means a great saving to taxpayers, for when roads with these modern bridges become a

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part of the state system the bridge problem is solved. And after all the people pay for the improvement whether the state, county or township builds it. Many counties now co-operate with the commission and ask approval of their bridge plans when building on roads it is reasonable to expect will some day be a part of the state system.

Foundations are most important in bridge construction. The difficulty of today is that many smaller county bridges have foundations resting on sand or on stream beds. When there is a question of doubt foundations should always be on piling. The day of the tread board or "half sole" floor on bridges is past. Because motorized traffic can not keep on this track and is shunted to either side, the side walls of many bridges are destroyed. In building or repairing bridge floors, make the surface uniform.

Rigid inspection should be enforced when bridges go up. With few exceptions contractors would rather build properly than improperly, but the mistake of weak bridges, especially foundations, is largely due to faulty engineering. Often 35 to 40 percent of the bridge cost is beneath the water, so should be of the best construction.

Abutments for steel bridges have, during the past two years, been designed so as to afford the easiest possible access to the steel castings or shoes which support the trusses. This permits careful driving of the rivets in the ends of the trusses; the accurate setting of masonry plates, castings and anchor bolts and does not leave a closed-in space around the ends of trusses where dirt, leaves and other debris are sure to collect and retain moisture that soon induces rust to the extent of seriously reducing the strength of the steel trusses. With this design of abutment and bridge seat, the truss shoes and end posts are easily kept clean and properly painted. Our maintenance patrol forces are instructed to be on the look-out for danger from this source and regular inspections are made each spring and fall.

Our old steel bridges were mostly built more than twenty years ago and were designed for very light loads, as compared to the modern heavy truck loads. Where these old bridges show, upon investigation and analysis, that they will have a probable life of ten or fifteen years, it has been our policy to repair the steel work and to replace the floors with new ones of creosoted wood blocks, supported upon heavy creosoted planking. Floors of this type, if carefully treated with pure creosote oil, make a very satisfactory permanent floor without adding much dead weight to be supported by the old steel trusses and floor systems.

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CONSTRUCTION OF CONCRETE ROADS.

By C. C. Mason,
Asst. Engineer, Marion County.

Our specifications for 1923 and 1924 will not permit piling material on the sub-grade. This leaves it up to the contractor to use a central proportioning plant at the railroad switch, which is the ideal method, or to stock pile at convenient locations and use proper measuring devices to insure the correct amount of aggregates for each batch. From the engineer's standpoint, the use of charging bins with a measuring hopper at the bottom and the transporting of the aggregates in light trucks to the mixer on the sub-grade and placing the cement from stock pile directly into the mixer skip, is the best method. It gives the inspector an opportunity to check his cement factor and watch the mixing, placing and finishing without leaving the mixer. With a uniform aggregate, the measuring hoppers will need very slight attention and adjustment.

When a central mixing plant is used, it should be so designed with measuring boxes or hoppers to insure the correct amount of aggregate and cement for each batch and will require an inspector to watch it. It is not desirable to have a lapse of time of more than 30 minutes between mixing and placing. The mixed concrete is generally hauled in Ford trucks equipped with 30 cubic feet dump beds and requires two to four men to unload the concrete from the truck. This method has been used on one of our jobs, but requires a water line for curing unless the calcium-chloride method is used.

Steel forms should be used exclusively and should be of a height equal to the thickness of the pavement. They should have a bearing surface on the sub-grade of not less than 48 square inches per lineal foot of form and weigh not less than 8 or 9 pounds per lineal foot. The forms should be well staked at intervals not exceeding 5 feet and should be set in an absolutely straight line. It is necessary for the contractor to provide sufficient forms for a day and a half's run in order that no form will be removed for at least twelve hours after placing. Forms should be set at all times at least 300 feet ahead of the mixer so the sub-grade can receive its final preparation without delaying the mixer.

The Mix.

On one course roads both the State Highway Commission and Marion County are using 1-2-3 mix. The State specifies a cement factor of 1.7 barrels of cement per cubic yard of concrete, whereas Marion County specifies 1.75 barrels for a stone

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aggregate, and 1.67 barrels for gravel aggregate. For the purpose of checking the amount of cement used, it is customary to reduce this cement factor from barrels per cubic yard to sacks per square yard or per lineal foot of pavement. It is also necessary for the inspector to check the cement at intervals not exceeding a half a day's run and when starting a job to check the cement every 10 to 15 feet until the measuring boxes are adjusted to give the proper proportions as required by specifications.

It is necessary to use measuring hoppers or boxes that can be adjusted to secure the correct amount of aggregate necessary to meet the specifications. A measuring device attached to the bottom of overhead bins is the ideal method. Where Ford trucks are used, the method of nailing strips or painting lines on the truck body to insure the correct amount of aggregate, will give good results but requires the striking off of each truck load first for the gravel and then for the sand. There is always a tendency to neglect the striking off of the truck loads on account of the time and labor involved especially when the contractor is pushing the job. Unless each truck is struck off, there will be a lack of uniformity in each successive batch, some containing a little more aggregate, which is generally the case, and some a little less. While the cement may check at the end of a day's run, some spots will have more cement than others. The road is no better than the weakest spot. Uniformity of each batch of concrete is absolutely essential to secure a good, lasting pavement, and too much care can not be exercised by engineer, inspector and contractor to secure these results.

Concrete should be mixed in a batch mixer for a period of not less than sixty seconds after all materials are in the drum, the mixer being operated at the number of revolutions per minute recommended by its manufacturer. The mixer should be equipped with a water measuring device to insure a uniform consistency in every batch and the amount of water used should be the least amount that will produce a workable consistency as every pint of water beyond this amount reduces the strength of the concrete. The mixer should be equipped with a batch meter to register the number of batches poured. For a mixer operating on the sub-grade, the discharging device should be of the boom and bucket type. The consistency should be such as to show a settlement of not over two inches in the slump test.

The concrete should be placed only on a moist sub-grade and should be spread the full depth and width of the pavement by shoveling. The use of rakes should not be permitted. Any manhole tops, railway tracks or other structures should be brought to finished grade before the concrete is placed around them. Concrete should not be placed on a frozen sub-grade.

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Finishing Concrete Surface.

After placing, the concrete should be struck off, tamped and finished by a finishing machine, so designed as to move either backward or forward and at such speed as to thoroughly compact the concrete and eliminate all voids. The machine should go over the concrete a sufficient number of times and at such intervals as will give the desired results. The strike board should cut the concrete at least ⅜ inch high to allow for tamping and must conform to the required cross-section of the pavement. Forms and wheels of the finishing machine should be kept clean and free from dirt at all times.

On curves, widened portions of the pavement or in such other cases as the engineer may direct, hand tamping and finishing should be substituted for the mechanical.

The concrete should be struck off by means of an approved template and should be thoroughly compacted with a hand tamper, meeting the approval of the engineer. Immediately after the concrete has been tamped, it should be rolled with an approved metal hand roller, having a smooth even surface approximately 6 feet in length, 12 inches in diameter and weighing not more than 1 pound per inch of length. The roller should be used just as soon as possible without displacing the concrete. In warm weather, especially with rock aggregate, if the concrete has not been mixed too wet, the roller may be used immediately. In cool weather, it may be necessary to delay the first use of the roller for 30 or 40 minutes. If the pavement is not over 20 feet wide, the roller may be operated from one side of the road to the other, by a long handle. If the pavement is much wider than 20 feet, it will be found more convenient to attach a rope to the roller and pull it from one side of the pavement to the other, discarding the handle entirely. In this way, it is possible to roll with greatest facility any width of pavement. The roller should always be moved transversely across the road at a small angle so that it will move lengthwise of the road about 2 feet each trip across. After the first rolling, the same area should be gone over again in about 15 or 20 minutes. The concrete should receive successive rollings at intervals of 15 or 20 minutes until little or no free water is squeezed out. This usually requires not less than 3 rollings, depending upon the amount of water with which the concrete has been mixed, and also on the temperature. The less the amount of water and the warmer the weather, the fewer the number of rollings required.

After the rolling has been completed, the pavement should be finished by two applications of a belt made of canvas or rubber belting not less than 6 inches wide and not less than 2 feet

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longer than the width of the pavement. The belt should be applied with a combined crosswise and longitudinal motion. For the first application, vigorous strokes at least 12 inches long, should be used and the longitudinal movement of the belt along the pavement should be very slight. The second application of the belt should be immediately after the water glaze or sheen disappears, and the stroke of the belt should be not more than 4 inches and the longitudinal movement should be much greater than for the first belting.

The edges of the concrete pavement should be rounded with an approved edging tool, having a radius of not more than one inch. The edges at expansion joints should be rounded with a tool having a radius of not more than ⅜ of an inch.

The finished surface of the pavement should be true and even. The contractor should be required to test the surface with a 10 foot straight-edge placed on the wet concrete parallel with the center line of the pavement. This straight edge should be applied to the center line and quarter points, and must touch the concrete at all points. Any high places should be cut down and any low places filled up until the finished pavement has a true and uniform surface. In finishing the pavement, this straight-edge should be so placed as to lap the finished surface at least 3 feet. Special care should be used at each expansion joint to insure a smooth surface on both sides of the joint. The straight-edge should be centered on such joints.

Too much emphasis cannot be placed upon the importance of the use of a straight-edge, because this method insures a trueness and evenness of surface of pavement not otherwise obtainable.

Curing of Concrete Surfaces.

After the concrete surface has been finished, as described above, it should be protected by applying burlap very carefully. The burlap should be placed as soon as possible after finishing, without marring the surface. This does not mean that the concrete would have to be anywhere near the final set. After the burlap has been placed, it should be kept wet by sprinkling with a fine spray of water until the concrete is sufficiently hardened to remove the burlap and place on the other curing material. The burlap should weigh at least 12 ounces per square yard and be in strips 40 inches wide and 2 feet longer than the width of the concrete to be covered. At the ends of the strips should be fastened either iron bars or wooden strips so as to prevent raveling and aid in handling them.

As soon as the burlap covering is removed, the surface should be covered with straw to a depth of at least 3 inches. The straw should be thoroughly wet and kept moist by sprinkling

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with water for a period of at least 20 days, under favorable weather conditions, and longer if the engineer so directs, during which time all traffic should be kept off the concrete by the erection of suitable barricades and maintenance of same.

On level stretches of pavement, the concrete may be cured by building suitable earth dykes to such height as will permit the entire pavement to be covered with water to a depth of not less than 2 inches. The water should be maintained at this minimum depth for a period of at least 20 days. This method is very effective but can be used only on comparatively level grades.

Another method of curing is to use not less than 2 inches of earth covering instead of straw. The same restriction as to sprinkling for 20 days applies to this method.

The use of calcium chloride is comparatively new but its use eliminates the necessity of a water line where a central mixing plant is used. When used, the surface of the concrete, after the removal of the burlap, should be uniformly covered with not less than 3 pounds of granular or flake calcium chloride per square yard of pavement. This treatment should not be applied under 8 hours after finishing and preferably 16 hours. The treated surface should be protected from rain for a period of at least 12 hours, or additional applications should be made following rains, to insure 3 pounds of calcium chloride per square yard of surface for a period of at least 12 hours.

Expansion joints should be provided by placing permanently in position, a preformed, solid body of compressible asphaltic compound reinforced on both sides with a high grade, asphalt saturated wool felt, for the full depth thereof. The joint filler should be a suitable bitumen which will not become soft enough to flow in hot weather or brittle in cold weather.

Our practice in Marion County has been the use of an expansion joint one inch in width placed across the pavement perpendicular to the center line of the road at the end of each day's run. All expansion joints should extend the full depth of the pavement. Edges adjacent to the joint should be rounded to a radius of not more than ¼ of an inch with a suitable tool.

Dowels of ¾ inch round rods 4 feet long should be used at each expansion joint. These dowels should be placed on 3 foot 6 inch centers and should extend 2 feet into each slab. The 2 foot length of the dowel placed at the time of quitting work should be wrapped in heavy paper to prevent bonding. The next morning these dowels should be pulled out about 2 inches to allow for expansion. The other half of the dowel should be bonded in the slab. It will be necessary to have holes bored in the night board to facilitate placing the dowels.

It has been the practice in Marion County during the last four years to specify 40 pounds of steel reinforcing per hundred

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square feet of pavement. However, beginning with 1923, we adopted the Illinois standard using a ¾ inch round bar, not bonded, with a steel contraction joint on the center line of roadway. We are also using ½ inch dowels 4 feet long spaced on 5 foot centers through the contraction joint to tie the two halves of the slab together. These dowels are bonded.

Concrete should not be mixed nor deposited when the temperature is below freezing. If, at any time during the progress of the work, the temperature is at, or in the opinion of the engineer would, within twenty-four hours, drop to 35 degrees fahrenheit the water and aggregate should be heated and precaution taken to protect the work from freezing for at least 10 days. In no case should concrete be deposited upon a frozen sub-grade.

CHANGES AND IMPROVEMENTS IN DESIGN AND CONSTRUCTION OF INDIANA STATE ROADS.

By J. T. HALLETT,
Road Engineer, Indiana State Highway Commission.

Design

During the short existence and activity of the Indiana State Highway Commission, there have been several changes made in the design and construction of its roads, a few of the most important of which I will mention.

When the construction of the Indiana State Roads started in 1919 there was a general feeling among road enthusiasts and engineers that where there was a fairly good road existing, the grade of the old road should be followed so as to have a better base for the new road. The Highway Department with this idea in view laid many grades following very closely the old grade. The result was short, choppy grades connected with short vertical curves.

The first plans put out by the Highway Department showed some vertical curves as short as fifty feet in length. Our experience has shown us that when following the grade of an old gravel or macadam road so closely it is an impossibility to get a uniformly compacted sub-grade so essential to eliminate cracking of the pavement. Our conclusions were that on entirely new construction, the old road bed was more of a liability than an asset, therefore we are now laying our grades with longer tangents and longer vertical curves somewhat disregarding the old road bed. In every respect it makes a better road. We are now using a minimum length of three hundred feet for vertical curves, as compared to fifty feet at the start.

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The first concrete slab built by the Indiana Commission was eighteen feet wide, six inches thick at the edges and eight inches at the center. The concrete was a 1:1½:3 mix. All of this was common practice at that time. The pavement section which is thicker at the center than at the edges is still good for types of road where there is no slab action in supporting the load and where the surface wear is a considerable factor in the destruction of the pavement. Concrete pavement under present day traffic does not wear to any great extent. The load is transmitted to the grade by slab action. Therefore a uniform eight inch slab was adopted and the mix changed to a 1:2:3. While we were not bothered to any great extent by longitudinal cracks, it is very desirable when cracks do occur that the slabs be kept from separating and the cracks opening. In order to do this it is necessary to put transverse steel in the slab.

In a recent design adopted by the Commission, this has been taken care of by one-half inch transverse bars spaced four feet apart. The corner of the slab is a weak point for supporting the load. We have always put ¾ inch dowel bars at transverse construction joints to transmit part of the corner load to the adjacent corner but only recently have we put in a continuous dowel bar at the edge of the slab to help transmit the load across transverse shrinkage joints. By strengthening the weak points in the slab by addition of steel, we believe that a seven inch uniform slab reinforced in this way is as strong or stronger than an eight inch slab not reinforced. The cost figures out slightly less.

The first brick pavements were grout filled but later the bituminous filled pavement was adopted. Recently the continuous dowel has been added to the base of brick and bituminous concrete pavement. The latest specifications provide for a 1:2:3 mix in the base of brick and bituminous concrete pavements instead of 1:3:5 as originally specified.

Construction

The building of the grade on state roads is practically the same standard practice as used everywhere and has not been changed appreciably since the Commission started operations. However, in our most recent specifications, we have provided a slightly different method of widening existing embankments. The specifications call for the old embankment to be torn down, widened to full width and thoroughly rolled before any additional material is placed. We believe this will cause better fills to be constructed.

The first contracts awarded permitted aggregates to be stored upon the subgrade and had no definite restrictions as to the cutting up of the subgrade by hauling over it. We find that

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this did not permit the proper preparation of the subgrade, so later contracts provided that all aggregates should be kept off the subgrade, at least five hundred feet in advance of the laying of the pavement, and no hauling allowed over the subgrade when the wheels cut down more than two inches. This provides a more uniform subgrade which is very essential in road construction.

We formerly checked the subgrade to see if it was the proper elevation by the string and rule method, now we use a templet which slides on the forms. This insures a more correctly shaped subgrade than the former method. About the time the Commission started construction, the finishing machines for concrete pavements were in their experimental stage. They were used on some of the first contracts, while on the others the hand finishing was used. The machine finisher produces a denser concrete and a smoother surface. Now finishing machines are used on all jobs.

On the first job a straight-edge was used for checking the surface only at construction joints, but now our inspector and the finisher check and re-check every foot of pavement before the concrete sets. This gives them a chance to correct a rough surface when it can be properly corrected. The result is much smoother pavements.

It has been determined by taking cores out of the pavements laid that the thickness of the slabs were quite variable. In some places the variation was nearly 50% from the required thickness. Since we have used more precaution in checking the surface of the pavement, also in checking the subgrade to see if it is the proper elevation, we find that the variation from the required thickness is usually not more than 10%.

While we do not feel that we have the final answer for slab design, we do feel our design will compare favorably with any other design of the same cost.

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MAINTENANCE OF CONCRETE ROADS.

By A. P. JONES,
Madison County Highway Superintendent.

The materials required for the repair of concrete pavements are portland cement, sand, stone, (crushed stone is better) and bitumen. Bitumen, for filling cracks and joints and for making shallow repairs, may be coal tar products, asphalt or asphaltic products. The hot bitumens at proper temperatures flow quickly and fill the parts of joints and crevices thoroughly but caution has to be exercised not to get the material too hot as this would burn or cook out some of the bitumen taking from it the elasticity which is required so that when cooled it would become brittle.

The equipment for this work depends on the extent of the repairs. If the work covers much territory, a light motor truck with a heating kettle mounted on wheels for melting the bitumen is the most convenient. A pouring can, a stiff broom, a sharp raking tool made for cleaning out the cracks and joints to be filled and a shovel for putting on the sand completes the outfit. The proceedure for doing the work is very simple.

The best way I have found to proceed with this work of sealing the crevices is to have one man go before with a good stiff house broom and sweep thoroughly the surface, removing every particle of dirt. Then another follows closely with a can of the bituminous material, pouring in enough to fill the crack and a third follows with a shovel and covers the asphalt with sand. The three men should work close together till the job is completed so the work of one will not be lost. If the sand is spread as soon as the asphalt is poured, it is not necessary to close the road and stop traffic.

Sometimes it is necessary to repair a worn spot or depression in a pavement due to faulty material, improper mixing, or freezing while the concrete is green. The following steps should be followed in making a patch of this kind: first clean the hole in the surface thoroughly of all dirt and loose material; then paint the area with a thin coat of bitumen; mix enough good washed pea gravel or stone chips with enough bitumen to fill the depression a little more than level full; settle this new mixture with an iron tamp to a level with the adjoining surface; paint the patch again with the bitumen; cover with a coat of good sand and the patch is done.

For patching holes more than an inch deep, a permanent patch may be made with concrete after cutting the hole out to a depth of three inches making the edges straight down so that

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no part of the patch will be less than one inch thick. The old concrete should be trimmed away until all loose material is removed and the surface and edges are perfectly sound. Then the edges and bottom should be made wet, taking care not to leave any water in the hole. Mix new concrete using as nearly as possible the same materials as used in the original pavement and in the same proportions except that the mixture should not be leaner than one part Portland cement, two parts sand, three parts pebbles or crushed rock. This coarse aggregate should be of maximum size corresponding to about half of the depth of the hole to be repaired. The concrete for the patch should be mixed immediately before it is to be used with just enough water to make it mix well. Place the concrete in the hole to be patched, tamping it firmly against the sides of the hole so as to leave no cavities. It should be allowed to stand for a few minutes to settle and dry, then it should be retamped. This should be kept up until it has been tamped the third time, letting it dry between each time of tamping according to the condition of the weather. It will dry much faster in hot or dry weather than at other times. The hole should be slightly over filled at first so as to take care of the extra tamping and settling of the mixture, in order that the patch may be as nearly level with the surface of the surrounding pavement as possible. After the third tamping the surface of the patch should be worked over with a wooden hand float taking special care to produce a good finish at the edges so that there will be no seam or crevice between the edges of the old and new concrete.

The berms of a concrete road should be up even with the surface of the pavement but no higher so that the water will not be held on the road but will immediately drain off to the side ditch and be carried away. It is a good idea to sow the new fresh berms with rye and later with timothy or blue grass, as the roots of these grasses will aid materially in preventing washing, and also add to the appearance of the road.

DRAINAGE OF ROADS.

By Don Heaton,
Benton County Engineer.

I know of no subject that is as much talked about, as generally agreed upon and as little practiced as road drainage. By this I do not refer to elaborately designed systems, but just the ordinary common-sense precautions that we all talk about and so often fail to carry out.

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From a study of the subject it seems to me that the time spent on highway investigations and research in the last 20 years could be divided in about the following proportions: on the design of new road surfaces, 80%; on the foundations, subgrades and drainage combined, about 20%.

A few years ago, when heavy motor traffic first began to appear, many roads failed because their wearing surfaces did not have the necessary strength to withstand the demands of heavy traffic even when supported on stable foundations and subgrades. Undoubtedly the failure of the early pavement surfaces has been largely responsible for so much attention being directed in late years to developing road surfaces that would support our present day traffic. Now, however, the rather annoying regularity with which some of the strongest and best developed pavement designs have failed in very recent years would indicate that subgrades and drainage are about to receive their rightful share of attention and that the above percentages are to be changed if not actually reversed.

One of the first problems that concerns the highway designer is that of making the subgrade firm and strong enough to bear up the loads that come upon the road surface. For illustration, it is not hard to conceive of this being accomplished by the construction of a heavy foundation of such great thickness that in spite of poor drainage the road would not fail, due to the enormous effective depth from the surface of the road to the base of the foundation. On the other hand it is just as easy to conceive of the same stability being accomplished with an extremely light foundation and a subgrade kept dry by elaborate and expensive drainage works.

Between the two extremes there must be some economical half-way point, the determination of which will tell us how much money to spend for foundation and how much to spend for road drainage.

This is one of the road drainage problems that the highway research man will have to solve in the immediate future. I wish him easy sailing, though I don't know of another problem that involves more variable quantities.

Until recently, no one thought much about capillary moisture as a possible cause of subgrade failures. The usual practice in draining a road is by means of side ditches, under drains of tile and stone, or both, to remove surface and ground water. In spite of all these precautions many well designed roads have failed on account of very wet subgrades.

Repeated accounts of such failures brought on a series of experiments by the Bureau of Public Roads, to determine something about capillary moisture and methods of meeting its effects

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by road drainage. Briefly, the results of some experiments in this line conducted by the Bureau of Public Roads are: that, under favorable conditions of soil texture and temperature, capillary moisture moved a vertical distance of sixteen inches to six feet in twenty-four hours; that horizontal capillary action is much more rapid than vertical; that water has been observed to move in a horizontal direction in distances ranging from seven to thirty-three feet in twenty-four hours; and that the quantity of water and the rate at which it will move depend upon the sizes of the pore spaces between the soil particles. If the pore spaces are small, the movement of water will be relatively rapid, and the amount of water held against the attraction of gravity will be relatively great. If the pore spaces are large, the vertical or horizontal movement of water will be slow and the amount held in the soil will be small.

Even the slightest consideration of these figures and findings must leave no doubt in our minds that the natural law at work through capillarity must be faced in the design of road drainage and road subgrades. Vertical capillarity has been successfully met in many cases by placing a layer of material of low capillary power such as heavy crushed stone or coarse screened gravel, directly beneath the pavement. Attempts to stop horizontal capillarity include the design of vertical concrete cut-off walls extending about three feet below each edge of the pavement, tile drains on each side of the road and with trenches filled with broken stone, and by waterproofing ditch banks and subgrades with crude oil or tar preparations, or combinations of all three of these methods.

A mistake sometimes made in road drainage is the attempt to apply farm drainage methods to highway drainage, especially in the underdrain systems. In many respects the two call for widely different plans and considerations. There are many cases where tile drainage is a complete success in farm land, while in an adjacent highway the tile drain might be a very questionable investment. Extreme rapidity of action in farm drains is not as essential as in road drains. If a farm drain is so designed that the water table is lowered beyond the limit of capillary rise for that particular soil, the drain had better not be put in, as the one form of moisture essential for crop growth is capillary moisture. On the other hand, the ideal drain for a highway is one that eliminates capillarity completely.

Apparently the best practice in road drainage in the immediate future is going to include extensive studies of soil conditions over the route of any proposed project. Standardized methods of drainage for mile after mile of road up hill and down, through cut and fill, will be replaced by adequate drainage plans to meet every condition of soil and moisture.

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CONSTRUCTION OF MACADAM ROADS.

By HOMER TEETERS,
Engineer, Jay County.

Due to the different traffic conditions of today, specifications for plain macadam construction should be changed. We all appreciate that the foundation is a most important item in road construction. It is an easier matter to resurface when a wearing course has worn out if originally a suitable foundation has been built. For this reason I suggest the following specifications for a macadam base:

Upon the well rolled and compacted sub-grade, the foundation course shall be built in two courses. Place uniformly a 4 inch layer of crushed limestone passing a 3½ inch ring and retained on a 1½ inch ring, uniformly graded. This course should then be gone over with a spiked tooth harrow or approved stone rakes to get a surface of stone as uniform as possible. This course shall be thoroughly rolled with a self propelled roller, weighing not less than ten tons, and rolling until the stone does not creep or wave ahead of the roller. A sufficient amount of stone screenings, from dust to stone passed by a ¾ inch ring, shall be spread uniformly on this course from piles which have been previously dumped alongside of the road, and well swept or brushed into this course with steel or rattan brooms until the voids are thoroughly filled. Then all excess screenings shall be swept off. Upon this course there shall be uniformly spread a second course of 4 inches using stone from 2½ inches to 1½ inches. This second foundation course shall be thoroughly rolled with a ten ton roller until the stone does not wave or creep ahead of the roller, after which screenings shall be applied in the same manner as in the first foundation course. This course shall be thoroughly rolled until no voids appear. Water from sprinkling wagons shall then be applied to the surface and the rolling continued, rolling in sections of not more than 300 to 400 feet. As the water causes voids to appear, additional screenings shall be added and rolled in until the foundation becomes solid and free from voids.

My reason for recommending a foundation built in two courses is that, by so doing, we can obtain a much firmer base. It is necessary for the average heavy type traffic to have at least 8 inches of thickness after compression, and it would be impossible to roll this all in one course and obtain the compression necessary for a well constructed base.

Due to present traffic conditions, the top course should not be watered and rolled as in former days, but stone passing an

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inch ring and retained on a ¼ inch ring with sufficient amount of fine material to give proper bond should be uniformly spread over the prepared foundations. This surface of ¾ inch chip can be easily maintained by dragging.

It is my opinion that the ¾ inch chip has solved the maintenance problem of macadam construction. In referring to the ¾ inch chip, I would not require this exact size in all instances, as varying conditions might require a slightly larger or smaller chip. I firmly believe that giving the proper attention to building of the macadam base, providing for a broad foundation, not too much crown and good drainage, the chip wearing surface will take care of a big part of our county traffic.

NEW DEVELOPMENTS IN ROAD MAINTENANCE.

By A. H. HINKLE,
Superintendent of Maintenance, Indiana State Highway Commission.

I shall confine my paper to a few subjects which will be of most interest to you either because of some new feature about them or because I believe their importance is such as to deserve emphasis in connection with highway maintenance.

Plugging Breaks in Roads During Spring Thaws.

Every spring finds us with certain bad places in our gravel and stone roads, and other types have been known to develop their "sink holes." These breaks occur sometimes year after year at the same place, due to wet weather springs or poorly drained places in the roadbed. I might cite as a concrete example, a mudhole we "plugged" four years ago this spring which a local citizen who was forty-eight years old, said had appeared every spring for forty years."

It is not uncommon for deposits of quicksand or such a quality of clay to be encountered that the breaks are expensive to repair while the wet season is on. For the plugging of such breaks nothing is better than a layer of cinders to be covered with gravel, stone or other road surfacing materials for a wearing surface. The cinders will "choke" the mud hole and destroy the high capillarity of the soil much quicker than gravel. The mistake must not be made, however, of putting on the cinders and not covering them, for the cinders have a very low wearing value and during the dry summer will wear and blow away rapidly.

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The Cause and Method of Preventing Corrugations in Gravel Roads.

Corrugations are formed in gravel roads when the traffic reaches a certain density. These corrugations are apparently due to the vibration of the car combined with the slipping or "kick back" of the drive wheel as it drops into the trough of the corrugation. The development of the corrugation is greatly accelerated after a rain by the water being splashed out of the depressions and carrying with it some of the gravel and sand. This accounts for the corrugations developing faster on flat grades.

While any grade of gravel will corrugate under certain conditions, it is apparent that some grades of gravel corrugate much quicker than others; or, stating this another way, we might say that practically all grades will corrugate after the traffic has reached a certain density.

These corrugations develop much quicker in gravels which lack cementing materials and that are deficient in the coarser pebbles. Gravels which have an excess of fine silica sand, which has little or no cementing value, corrugate quite readily. It is very noticeable that gravels containing materials which cement them together, corrugate much less. We frequently have reduced the corrugation very extensively by the addition to the ordinary gravel road of a thin coat of crushed gravel passing a one inch opening and containing all the dust incident to crushing. Also, crushed limestone of the same grade can be used in the same way. Roads made of limestone which are maintained by the dragging process as the gravel roads are maintained, corrugate much less than the average gravel road. At least a partial explanation of this is apparently the greater cementing value usually possessed by the crushed stone. Stone roads not properly maintained are more inclined to develop pot holes instead of the rythmic corrugations developed by the gravel.

I have noticed frequently that gravel in which the pebbles are slightly coated with clay or calcium carbonate resist the corrugation quite well. It is also quite noticeable that the addition of thin coats of new gravel, of whatever kind, will resist the corrugation better than an old surface where the gravel and sand seem to be worn out.

The method of maintaining and dragging has much to do with the preventing of the corrugations. Our experience has fully determined that the corrugation is greatly reduced by the use of a very heavy drag or grader such that the surface is planed off smooth at frequent intervals. The heavy machinery will not vibrate and bounce up and down on the road surface as will the lighter drags, thus producing the incipient corrugations

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themselves. Wherever light drags or very light graders are used under heavy traffic, the corrugations seem to be more certain to form. For that reason we have been using a very heavy drag.

Some of the conclusions which we might draw from the above are as follows:

The corrugations are apparently formed by the vibration of the motor vehicle combined with the slipping of the drive wheels as they go down into the trench of the corrugation.

While all gravel will corrugate to some extent when traffic reaches a certain density, gravels are very different in their nature and some corrugate much worse than others.

Gravels containing an excess of fine sand and a deficient amount of the coarser pebbles, from which cementing material is absent, corrugate most readily. This is perhaps explained by the little resistance offered by sand grains of uniform size to being shoved aside by vehicles. In other words, the greater percentage of voids in the gravel or sand which would exist when the grains of sand are of quite uniform size would permit corrugating most readily.

With the above explanation of the causes of corrugations it is quite evident why the following methods of preventing corrugations are effective:

The frequent additions of thin coats of new gravel will aid materially in keeping down the corrugation. This is perhaps nothing more than saying that a new road is better than an old worn out one.

The application of crushed gravel or crushed stone will greatly reduce the tendency of gravel to corrugate. This no doubt is due; first, to the greater density of the mixture; second, to the cementing value of the dust, and third, to the greater resistance the angular pieces offer to being shoved aside.

The dragging and smoothing of the surface with a heavy drag, plane or grader will greatly reduce the tendency of the road to corrugate. This latter means of keeping down the corrugations is extremely important under heavy traffic.

Dragging of Bituminous Surface Treated Roads.

An innovation was started this past summer in one class of our maintenance work by dragging a road just after it had been given surface treatment of bituminous material and clean stone chips. After experimenting with an especially made drag for this purpose and an ordinary road maintainer our conclusion is that perhaps our standard Type "B" drag is the most satisfactory piece of equipment for this purpose, although the road maintainer gave very satisfactory results.

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It frequently happens that a macadam road which is maintained with bituminous surface treatments is quite rough or irregular. The irregularities in the surface may be greatly reduced by applying a treatment of tar or asphalt and putting on a limited amount of stone or gravel covering after which the surface is dragged as an ordinary gravel or stone road. The drag places the stone or gravel pebbles, which have been coated with asphalt or tar, into the little holes or depressions in the road surface thus leveling up the surface. Part of the work which we did along this line this past summer received a second coat of tar and screenings. It is necessary that the tar or asphalt be just sticky enough so that the pebbles will be moved by the drag and yet will stick in the location the drag places them and not be readily displaced by traffic. This means that the dragging would have to be done immediately after the application if the tar or asphalt was quite a heavy grade of material and applied during the cool weather. On the other hand, if the tar or asphalt was a light grade of material and was applied during the hot weather it would be necessary for some little time to elapse between the application and the dragging if the best results are to be secured.

Since this work has been made public some of the other States have already dragged their surface treated gravel roads. I see no reason why this method of smoothing a road surface after it has been given a bituminous treatment cannot be used to great advantage on many roads of the cheaper type.

Sizes of Stone in Bituminous (Penetration) Macadam Work.

It has been fully demonstrated that many of the penetration macadam roads have been made of too small sized stone. The small sized stone not only are more susceptible to being displaced by the heavy traffic but are also much more apt to produce areas in the stone where the voids are completely closed by the rolling and thus produce spots where the asphalt or tar cannot penetrate. The finer stone prevents sufficient rolling of the course which is necessary before the application of the bituminous material in order to produce a rigid surface when completed. It is well demonstrated that stone through a 4 inch circular opening is none too large for use in this type of road.

It is important to guard against applying too many screenings after the bituminous material is applied and before the surface is rolled. It might be said that in the rolling of all macadam work, whether bituminous macadam or water bound macadam, the greater part of the rolling should be done so that the roller wheels will come in contact with and press upon the coarse stone. Ruts or depressions made in the layer of big stone in the surface should be removed by rolling on the big stone so far as

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possible and not by filling the rut with small stone. As soon as a "bridge" or mat of fine stone or screenings separates the surface of the roller wheels from the coarse stone, a surface is being produced that will wear irregularly under traffic, although the surface may be smoother when finished than the proper method of rolling will produce.

Repair of Concrete Roads.

At present it is quite generally conceded that the use of a bituminous material for filling cracks in concrete roads is the most economical. The best grade of tar for this purpose that we have been able to specify is a tar meeting our T. P.-2 specifications. This material is heated in a kettle and poured into the joints and covered with sand. This tar is softer than our standard penetration tar, the latter being so hard and brittle that it chips out in winter.

The best grade of asphalt we have found is asphalt emulsion meeting our A. E.-1 specifications. This material is poured into the joint cold and covered with sand. Either of the above materials are suitable for making shallow or skin patches. Asphalt similar to that used in penetration macadam and known in our specification as asphalt filler A. O. F.-1 has been advocated and used very extensively for this purpose for a number of years. Our experience has been that this grade of asphalt if used on roads which have a heavy winter traffic is of very little or no value. It is chipped out by traffic in cold weather so that when spring comes there is hardly a trace of material left on the surface.

The larger cracks and bigger depressions in concrete roads should be filled with a mixture of bituminous material and crushed stone. For this purpose either the cut back tar (our T. C. M. specification) or asphalt emulsion, mentioned above, may be used.

Where it is necessary to replace a good sized area of concrete surface, which is in excellent condition otherwise, it may be desirable to make the repairs out of concrete similar to that used in the original construction. The trouble has been that these patches had to be protected against traffic for a number of weeks which was quite a handicap. However, recent developments have shown that it is possible to make concrete by using the proper mixture, amount of water and compression in placing, together with the addition of a small amount of calcium chloride, which will cause the concrete to assume as much strength in four or five days as ordinary concrete assumes in three weeks. If this process proves practical it is possible that many repairs made heretofore with bituminous materials could be better made with concrete.

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System of County Roads.

It sems that we have advanced sufficiently in our highway work in the state that every county should have a definite system of county roads which should be selected with some consideration of the county roads in the surrounding counties. These roads, in order to distinguish them from the state roads, might be designated by letters, as is done in Wisconsin. The necessity of knowing where and what such a system of county roads consists of is made more necessary at the present time due to the fact that part ($500,000 the first year and $1,000,000 per annum thereafter) of the gasoline tax is to go back to the counties for road maintenance. According to the law, one-half of this is to be divided equally among the counties and the other half is to be divided among the counties "in the proportion which the number of miles of free gravel or macadam and county unit roads in the county bears to the whole number of miles of such roads in the State."

It is the duty of the State Highway Department to determine the mileage of these roads in each county. It is only with the co-operation of the County Highway Superintendents and County Surveyors that this mileage can be readily and accurately secured. It goes without saying that the State Highway Commission expects your full co-operation in this work.

Superintendents With Backbone Needed.

You highway superintendents, whether working for the state or county, are in such a position that you are subjected to various influences both good and bad. The good influences are such as to stimulate you to do more and better work for the money you expend, or in other words to be a credit to yourself as well as your community by maintaining the roads under your supervision in the best possible condition with the limitation of funds and other restrictions placed upon you. The public is expecting this from you. This is what they are paying you for. You will be criticized at times, of course, for doing your duty. There are greedy citizens who unless they can have you serve their selfish interests at the public expense will criticize you. However, here is a test of your backbone. Will you yield to the demands of selfish interests when you know it is at the expense of the general public or will you keep a stiff upper lip, do your duty and take the unjust criticism? If you yield to every selfish interest, who howls and bellows the loudest, by doing that which you know is unjust to the interest of the taxpayers who are paying you, then you are too much of a jelly fish to hold the responsible position entrusted to you. We must have highway superintendents with backbone. You will lose out occasionally by

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doing right it is true, but not nearly so often as in doing wrong. It is far better that you lose your position by doing your duty than by failing to do your duty.

Co-operation Between County Highway Superintendents and State Highway Superintendents Necessary.

It frequently comes to my attention that some of our employes are in more or less conflict with local road officials because of either the county or state having a monopoly on certain supplies of road material. While each must have certain rights and responsibilities, it must ever be remembered that the taxpayers of the state are paying the bills and that if either set of officials can accommodate the other in any way without sacrificing to any extent his own work, it is his full duty to do so. A man can **be smaller than his job,** as **big as his job,** or **bigger than his job,** according to his treatment of others associated with him either directly or indirectly. Regardless of whether or not we may have exclusive lease on a pit, we do not expect to bar the counties from securing gravel from the pit where it is not necessary to do so, and where it would be a great convenience to them to secure such gravel. Likewise, I feel that it is the duty of the county to co-operate with the state to the same degree. You should not forget that while you occupy one position this year that you might occupy the other position another year; that we are all working to the same end, and that is to provide for the people of the state a convenient and economical means of transportation.

HIGHWAY MAINTENANCE FROM THE STANDPOINT OF SERVICE, SAFETY AND ECONOMY.

By G. C. DILLMAN,
Deputy Commissioner and Chief Engineer, Michigan State Highway Department.

There are some general requirements which any maintenance organization must possess, chief among them being fixation of responsibility. Without this being definitely placed and commonly understood and respected by each party affected, positive control over the work would be lost. The employee must be loyal to his superior authority. Fairness combined with discipline not only creates respect but there is inert driving power in it. To permit men in lower ranks "to go over the heads" of an immediate superior, tends to confusion and jeopardizes efficiency.

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Each employee being assigned to some particular work, it is necessary that he be skilled in that particular thing he has to do. Here is a wonderful opportunity to carry out the apprentice system in road maintenance. A man begins at the most menial thing and, making good, is advanced to more responsibility. In this way an employee in a responsible position is familiar with all of the details of the work under him and efficient results will be had.

It is said that in a certain railroad executive office hangs a card which reads: "If the President of this Railroad should quit tomorrow all the company would have to do would be to hire a new office boy." Should not the same principle of organization as this card conveys be built into state and county highway departments? Possibly it is too much to hope for such an ideal condition of things, but by not working along that line thousands of dollars are annually wasted due to the questionable tenure of office or employment regardless of service. Continually breaking in green men on jobs requiring sound judgment, technical knowledge and experience, is done at the price of efficiency. This frequent turnover in personnel may meet with the approval of the public, in fact it appears at times that the public demands it. But, instead of gradually **building up** an efficient organization, one is **maintained** that tends to experiment upon the public with all the "new ideas" acquired with each change. On the other hand a maintenance organization must not be allowed to get into a rut formed by usage, routine or self-emulation.

The demands our highways are being called upon to meet are so great and changes in the methods of doing things are so rapidly taking place, that each man must study carefully his problems and develop his power of observation and application.

The organization we would have cannot be made up of misfits and function properly. The problem of maintaining our highways today is becoming more and more complex. It is not like construction with its specifications definitely laid down, hence the necessity for men having initiative, the ability to meet and overcome resistance and an inclination to serve the public with the best.

To maintain roads economically in a first class condition, the maintenance must be systematic and continuous. Systematizing the work requires a careful study of all the activities and the relation of each with the other. The different units must respond quickly to demands made upon them and to the proper directing authority.

The fact that our highways, no matter how well built, will not render continuous and efficient service without proper maintenance, is evidenced wherever the roads are only now and then

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given the "once over." The amount and frequency of maintenance required depends somewhat upon climatic conditions and the nature and amount of traffic, due consideration being given the type of wearing surface. However, with the traffic increasing as it has been in recent years, the pass word for the maintenance organization might well be—"continuous work."

Experience has proven that the patrol system of maintenance must be installed to insure good roads at all time. When this system is functioning properly it will do wonders since the responsibility for the upkeep of a certain section of road is placed upon one person only. The whole organization is founded upon the patrol unit. Each section consists of a fixed mileage and when possible the patrolman should be stationed near the center of the section to which he is assigned. When choosing patrolmen, the maintenance superintendent should endeavor to get men who take more than passing interest in their work. A man placed in this position should be a good worker and be willing to take advice and learn. He must demonstrate his ability in this work and should, at all times, be courteous to the traveling public.

There is perhaps nothing more annoying to the highway user as he drives along the road than to have his attention repeatedly called to something that has been neglected. This may be a hole in the road surface, a washout in the grade, a broken down culvert or one of a thousand things. Neglected maintenance is an advertisement of slipshod methods, is the most expensive in the end and breeds disrespect for the highway and its keeper. We should, therefore, remedy these defects promptly and, instead of trying to keep a roadway in as good condition as when it was first built, strive to make it better year by year.

If this is not done, we will soon find ourselves vainly attempting to handle traffic under hazardous, if not impossible, conditions. One thing is certain and that is the motor vehicle is not going back to the day of the ill-kept highway. Rather, it is setting the pace for a highway development whose limits can scarcely be predicted. And when we speak of highway development, it is not wholly construction or reconstruction or maintenance. The big job is to maintain the road already constructed in good condition, the road that should be reconstructed and the road that is unimproved and perhaps breaking down.

What is wrong when a state or county maintains its roads well for a period, then neglects them? The answer is—organization. Results obtained will depend largely on the man in responsible charge, whether he be engineer, superintendent or commissioner. This man must be thoroughly familiar with the work at hand. He must be capable of handling men and should have a good working knowledge of machinery used in road work.

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Maintenance departments must organize and equip for fighting snow. In many cases the regular maintenance forces and equipment can be used effectively. The principal thing is to be ready for fighting snow ahead of time and the work should be started as soon as the snow begins to fall and every possible effort made to prevent drifting. On account of the uncertainty of the work, and the probability that much snow removal equipment will be used only a few days during the season, taking the entire years interest and depreciation charges, the economic solution may be impossible, yet avoidance of serious traffic delays and interruptions will fully justify such work. In case snow removal is confined to a limited mileage, it is important that continuous routes be laid out without regard to county lines.

Safety Requirements.

Until quite recently, highway construction and maintenance was carried on with little regard to the element of safety. This is now considered one of the prime requisites of modern highway construction and a design that overlooks this is not good. There are a great many things entering into the design of a highway and until this time the design did not take into account the great volume of fast moving traffic. During these years thousands of miles of roads have been improved—the last word in highway construction being carried out. Then, a few years later, we find that many details of a construction nature must be added through maintenance. Road authorities must acknowledge the necessity of safe highways and devise methods of making them such.

During recent years much has been accomplished along this line but we have only begun. Maintenance forces must assume the burden of this work and maintain the highways for both safety and service. With the constantly growing volume of traffic it may be assumed that the number of accidents on the highways will proportionately increase, yet by safe driving together with the elimination of danger points, accidents may be reduced to a minimum. No matter where you go it is easy to find points on the highway which were comparatively safe for traffic a few years ago, but which are now the cause of many accidents. These dangerous conditions must be eliminated.

Sharp curves should be eliminated by lengthening the radius to not less than five hundred feet or by relocating and, on the most important main roads, all curves should be super-elevated having a radius of one thousand feet or less. Low type surfaces such as gravel and macadam tend to loosen and wear away rapidly on the inner side of sharp curves. Frequent replacement of material should be made and an effort made to keep the surface as compacted as possible.

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The surfacing of main highways should be at least eighteen feet wide since the maximum width of truck bodies generally run about eight feet and there must be reasonable clearance for two lines of fast moving traffic.

Grades should be of uniform width and the shoulders must be sufficiently strong to carry turn-out traffic. Shoulders should be wide enough—say five to six feet—on all heavily traveled roads so vehicles may drive out on them and not interfere with moving traffic. A law was recently enacted in Michigan which prohibits vehicles from parking on the traveled portion of the highway. To abide by the law at all times and in all places may mean inconvenience for the driver but it is a great aid for highway accident prevention and should be adopted by all states. It would be well to note that this requires widening narrow road grades which is usually a matter of maintenance.

Good sight distances for both horizontal and vertical curves intersecting highways and railroad grade crossings should be obtained. Trees, shrubbery and obstructions of any kind, regardless of value, should be removed if by so doing the location will be made more safe.

Fruit stands, loading platforms and gas and oil filling stations should not be tolerated at the edge of the road grade. They are a source of danger and congestion to traffic and often interfere materially in maintaining a road grade and drainage.

Protection along deep road ditches should be afforded by means of well built guard fence constantly maintained with a white surface. The fence should be so constructed that in case it was struck by a motor vehicle there would be no danger of a section of railing going through the car, possibly injuring an occupant of the vehicle. In my judgment, a well built cable guard fence is the safest for highways and the most effective.

Many times the low type road built some years ago has an excessive crown. This should be cut down to a point where it is not a source of danger to the motorist.

As a rule pavements have been built where traffic demands are heaviest and we should do everything to safeguard traffic. An effective means of traffic control is to paint lines from four to six inches wide down the center of pavements, thus providing lanes which serve to divide and direct traffic. This should be carried out at least around curves, preceding bridges and narrow places in the road, approaches to steep hills or any place where there is a danger from overlapping traffic. The addition of a traffic centerline increases the safety to highway users as shown by observations of the habits of drivers on marked pavements. This is something that the traveling public welcomes and it promotes confidence for the driver when in heavy traffic.

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I feel that center line marking of pavements is so essential to present day traffic that I will describe a method originated in Wayne County, Michigan, and adopted by a number of other Michigan counties. The outfit consists of a Ford truck on which is mounted a compressed air machine. A wooden wheel two feet in diameter and four inches wide covered with felt about one inch thick, revolves on an axle supported by framework attached to the rear of the truck. The wheel is placed on the left side of the frame so it will follow the left hand wheels of the truck. As the truck is driven down the road, the paint is applied to the felt about one foot above the pavement and is, in turn, transferred to the pavement as the wheel revolves. With such equipment two men can mark five or six miles of pavement per day which makes the cost very reasonable.

There is no such thing as a safe railroad grade crossing, but granting a crossing is not to be eliminated by relocation or the grades separated, we have the grade crossing to maintain in as safe a condition as possible. Care must be taken to see that the crossing is smooth. The most desirable crossing is one that is paved or has been given a substantial bituminous surface. At all grade crossings on dust laden roads, a section five hundred feet in length each way from the crossing should be treated with a dust layer. By keeping the dust laid the driver's vision is not impaired and the treated strip is a reminder to him that a grade crossing is near. The crossing should be planked or paved for the full width of the traveled way at least, preferably to the full width of the road grade.

In the interest of public safety all advertising signs and obstructions along the highways should be removed. This might include the setting back of rural mail boxes such that traffic would clear the box and post.

Reports should be required on all highway accidents and these filed with the proper highway authorities. The report should give the location and cause of such accidents and when these are compiled and studied it would be of great value to a road department as a guide in planning further improvements to reduce accident hazards.

It is only a question of time, I believe, when our heavily traveled roads will be policed and with the aid of rigid legislation, the motor vehicle driver will have more respect for all users of the highways. Regardless of the fact that the roads are being maintained in a safer condition all the time, there seems to be a growing indifference on the part of motorists.

It is evident that our duty is not only to maintain the highways in good condition, pursuing the work in an economical manner and with the least possible inconvenience to traffic, but

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the frequency of highway accidents continue to be one of the outstanding problems. There is something wrong when motor vehicles annually take a toll of human life in the United States comparable to that great catastrophe, the World War. The solution may lie in part to proper education of the driving public, yet great responsibility rests upon road maintenance organizations.

Dust Prevention.

There are many reasons why roads should be kept as near dustless as possible. The enormous quantities of dust annually swept from our lower type roads proves a nuisance and is unhealthful not only to people traveling the highways, but to persons, live stock and vegetation adjacent to them. Clouds of dust add an extra element of danger to people using the roads. Material blown or swept from the road itself is lost and must be replaced at a big annual expense. These are but a few of many objections that might be named as a public menace.

There are two general ways in which the dust problem on gravel roads may be solved—by retaining the dust on the road surface and by preventing its formation. Materials such as calcium chloride and oils are commonly used with varying results. The results obtained are only temporary, hence the amount that can be economically spent for such treatments is not great.

The use of refined tars for surface treating gravel roads has had considerable attention in recent years, and excellent results are being had. The solution to our problem is to apply a bituminous material which, when applied properly, will render the gravel road dustless, grip each individual particle in the road surface and hold them together, enabling the surface to be maintained economically in a smooth and satisfactory condition. The big thing is to maintain the surface in an unbroken condition which necessitates patrol attention.

Road Marking.

One of the most important functions of a maintenance organization is to adequately mark the highways under its jurisdiction. Automobile clubs, associations, civic organizations, business interests and others have attempted to mark, in one way or other, the highways long enough. The time has come for both county and state to agree upon this matter and get into action. The Mississippi Valley Association of State Highway Departments has probably done more in the way of standardization of highway signs than any other group. Last year this association made some very definite recommendations on caution and warning signs that are applicable for county and state alike. In addition there should be erected standard distance and direction

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signs throughout the state. There is no plausible reason why one state should have caution and warning signs different than another state—nor one county different from another county or state in which the counties are located.

Motorists are quick to make comparisons of the highway service rendered by different organizations. The condition of the highways largely determines the pleasantness of the trip, but the marking or lack of it makes the impressions that are not soon forgotten. So let us forget county and state lines and post our highways with uniform signs promoting safety and convenience to the traveling public.

If a county or state highway maintenance organization wants to make a decided hit with the public, then maintain all detours well. The motorist has too long considered the detour as a veritable appendix on the road system and he has been largely right—why? For the reason that it was a trouble maker and no part of the organization, construction or maintenance, wanted to adopt it.

We know the average driver of a motor vehicle is prejudiced when it comes to detours, but let us do our share and he will generally be tolerant to the extent of his. Don't close the main road and then start to maintain a detour—just change the system about and see what a soothing effect it will have on the driving public. Give the detour fully as much attention as the road for which it is intended, and with the right kind of marking and patrolling, the big troubles will be removed.

There can be no such thing as efficient maintenance without the work being planned some time in advance of its being done. It takes a number of years to develop a good maintenance organization and during that time a program is being worked out that is imperative for economical results. A man cannot pick up in any one or two seasons, the many details of this work and become familiar with the history and behavior of the various roads he may have under his control. A road must be "known" to be handled in an economical way and when this is the case, much trouble and expense may be saved. In other words, it is much better to prevent certain things from developing on a road than to try to correct what might have been avoided. This is where a man's full knowledge of conditions he has to work under pays good dividends in service and economy.

It is important that accurate costs be kept on the maintenance of different roads and of different types. These costs should be studied from year to year and are of great value when adjusting the annual budget.

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MATERIALS FOR ROAD MAINTENANCE.

By W. S. PARKS,
Jasper County Highway Superintendent.

In order that you may get an idea of the extent of the operations in Jasper county where I am employed, I will give very briefly the road statistics of our county. We have 443 miles of stone and gravel roads that are maintained by the road superintendent—139 miles of gravel and 305 miles of stone. There are 108 bridges. Three of them span the Kankakee river, a distance of 170 to 180 feet; 7 are over the Iroquois river, a length of from 75 to 100 feet; 7 are over other small streams, 75 to 100 feet; 3 are 12 ft. span, and the other 88 will range from 20 to 75 feet.

The total amount of money available for road maintenance in 1923 was $48,000, in round numbers. $20,050.30 was spent for stone and gravel; $3,164 for culverts; $528.42 for tile; $4,941 for concrete headers, etc., including labor and materials; $3,600 for cleaning and painting the 108 bridges, including labor and material.

The kind of gravel I prefer for road maintenance is one which will not be coarser than one inch and have not more than 25% to 35% sand. Stone, about the same size, crusher run, I find the most successful.

I believe that spreading road materials over a road in a thin layer and repeating this often will get the best results. In the north end of our county, where the roadbed is of sand and muck, I find that one inch material is most satisfactory; while in the south end of the county, where the foundation is more firm, being a mixture of sandy loam and sandy clay, a three-quarter inch crusher run stone or pike gravel makes the best road. Both the stone and gravel should be relatively clean—that is, with very little dust or clay. Particularly, clay is unsatisfactory, except in small quantities when it would be permissible for quick binding. With the kind of materials described and plenty of dragging twice a week on main roads and once a week on side roads, our highways are kept in what we consider a good condition. During the spring breakup, three-quarter inch to one inch crushed rock or clean gravel is used to fill the worst places. These places are then marked and tiled during the following summer. This treatment usually prevents the trouble occurring again.

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FORECASTING HIGHWAY TRAFFIC.

By W. K. Hatt,
Professor of Civil Engineering, Purdue University.

Knowledge of the future highway traffic is important in planning a state wide system of roads. These roads are to carry vehicles in the same sense as a town water system carries water. No engineer would lay out a system of pipe lines for a water supply unless he had looked ahead for a term of years to judge the growth of the city, so as to be sure his system would fit future conditions.

Likewise if we are to build roads wide enough and in the proper places to discharge the flow of traffic, we must look ahead and secure right-of-way and plan the roads according to our best estimate of the amount of traffic that is likely to flow over these roads.

There is another important reason for forecasting traffic. The total cost of highway transportation is made up of two parts —the cost of maintaining the road and operating the vehicles. We cannot calculate the economics of this business of road construction until we know the cost of operation which far exceeds the capital cost of the road.

The distribution of this future traffic over a system of state roads should be known rather than the immediate distribution. A paved road immediately draws traffic to it, and later on this peak of traffic may be dispersed to neighboring roads whenever these are surfaced.

Knowledge of traffic will also aid a wise allocation among the various parts of the system of the state funds which are to be spent on construction and maintenance. This can be done only approximately when there is only a general impression of where the traffic is now going and where it will go in the future.

These traffic problems are not confined to rural highways. The acute problems are those of the cities. Indeed city planning experts must study the automobile traffic. I know of one case where a bridge engineer had first to solve a traffic problem before he could design his bridge.

Another very important reason why traffic surveys should be made is that we may determine the proper place which highways should occupy in the structure of national transportation. As a rule people vitally interested in railways are not the friends of highway budgets, and with their present information they may be expected to attempt to slow down the flow of public money into highways. After all, there is only a certain portion of the

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national income available for transportation, and what is put into one form to a necessary degree will act as a starvation of other forms. The railway men fear that they are paying taxes to create free highways for their competitors. Now a thorough survey of the origin and distribution of taxes used in highway construction operation is necessary to adjudicate questions of this kind. As a matter of fact, there is very little basis for the statement that the railway lines are largely contributing to establish a free highway for their competitors. It is also true that a long and painstaking transport survey in the state of Connecticut has shown that the amount of freight traffic carried over the highways in competition with the railroads is quite small. Professor J. G. McKay of the Bureau of Public Roads has reported these facts from the technical press, where they may be consulted. Traffic surveys of this kind are useful in quieting unnecessary controversies and bringing people together for a co-operative purpose.

We cannot predict highway traffic until we have such a collection of facts. The future can only be forecast from a knowledge of the present and the past. Here we have to do with such facts as the increase in population, the increase in the registration of automobiles and the growth of highway traffic as connected with population and automobile registration.

To the astonishment of most persons, the automobile registration in the United States increased from almost twelve and one-quarter million in 1922 to over fifteen and one-quarter million vehicles in 1923. Manufacturers expect to sell four million additional cars in 1924. There is now one car for every 7.2 persons in the United States.

In Indiana registration increased from 469,939 in 1922 to 582,882 in 1923, or one car for every 5.1 persons. In Indiana the increase in automobile registration was 24 per cent, while the population increase was less than 1 per cent. How long will this remarkable increase continue? Shall we have one car for every 3.8 persons as in the case in Iowa at present?

There are a number of obscure factors as for instance, the wealth of the state; the present distribution of cars as between the rural and city population; the progress of road building, which determines the use of the cars; the general prosperity of the state. There must be some limit to the number of persons per car, a so-called saturation point.

Some study of this future traffic has been made by Mr. Dillman, Deputy State Highway Commissioner of Michigan. He projects the population line in a uniform increase and compares this with the increase in motor vehicles. His predictions are based upon a period of ten years up to 1923. At the end of this

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period there will be one vehicle for every 4½ persons, and the rate of increase in registration will be one percent a year, or a parallel to the increase in population.

Applying this same method to the State of Indiana and allowing 1 car to 4 persons, we have the following result:

The estimated population of Indiana in 1932.....3,200,000.

One car for every 4 persons approximately .....800,000 cars. But who knows? The data of population and registration are in Tables No. 1, 2 and 3.

Next it may be inquired if the traffic on the road will increase with the number of automobiles. If we double the number of automobiles, will we double the number of cars on the roads against which maintenance funds must be obtained to preserve the surface of the road? The laws governing the use of the roads are obscure. The best information at hand indicates that road use does not increase as fast as automobile registration. In New Jersey it is calculated that in 1940 there will be 2.7 times as many cars as at present, but only one and one-half times the present flow of traffic.

Traffic surveys are of additional value as a basis for legislation to govern the use of the roads with respect to axle loads and to the class of roads on which a given vehicle may run at various seasons of the year.

It is a curious thing that the three neighboring states of Ohio, Indiana and Illinois, that have such a vital interest in the scientific road development, have no extensive data on highway traffic. It is hoped that the Highway Commission will provide the necessary funds and forces to collect the needed information through a systematic plan for traffic surveys. I am sure Purdue University will be willing to co-operate.

Table No. 1.

Population of Indiana

Year	Number
1880	1,978,301
1890	2,192,404
1900	2,516,412
1910	2,700,806
1920	2,930,390
1932	3,200,000 est.

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Table No. 2.

Automobile Registration in U. S.

Year	Number
1916	3,512,996
1917	4,983,346
1918	6,146,617
1919	7,558,848
1920	9,211,295
1921	10,448,632
1922	12,239,114
1923	15,250,000

Table No. 3.

Automobile Registration—Indiana

Year	Number
1913	44,738
1914	66,410
1915	96,615
1916	139,117
1917	192,195
1918	227,160
1919	277,255
1920	333,067
1921	400,342
1922	469,939
1923	582,882

Possible Registration:

1924	635,000
1925	680,000
1926	715,000
1927	740,000
1928	760,000
1929	775,000
1930	785,000
1931	795,000
1932	800,000

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RELATION OF COST OF ROADS TO THE TRAFFIC.

By T. R. Agg,
Professor of Highway Engineering, Iowa State College.

In economic comparisons of the various means that may be available or may be made available for conducting highway transportation there must be consideration not only of those costs that accrue on account of the vehicle, but also the highway costs. Actually these are closely related and quite often vary together. The total, or more properly the true cost of highway transportation is a combination of vehicle costs and highway costs and neither is complete without the other.

It is difficult to ascertain the true cost of highway transportation because the vehicles are under the ownership of millions of individuals, most of whom make no attempt to keep records of the cost of vehicle operation and the roadway is publicly owned and is administered by officials who may or may not keep complete records of cost, (usually they do not).

The mutual adaptation of road and vehicle to the end that transportation costs will be a minimum is almost wholly impossible under these conditions. To begin with, authoritative data on costs is lacking and officials cannot therefore determine with certainty what policy to adopt, and even if they did formulate a policy, the administrative problem of securing harmonious and concerted action by the builders of highways and the manufacturers of vehicles is a tremendous one. The matter is still further complicated by the fact that both groups (public officials and vehicle manufacturers) must in the last analysis depend upon public support to make their actions effective. The public cannot sense that there are broad economic problems involved in the development of a highway system and can but dimly comprehend the basic principles when they are expounded.

The public cannot by any stretch of imagination be conceived to have more than a remote conception of the economic loss that results from improper highway design or construction. This loss is unquestionably enormous but it is made up of millions of small items that are concealed in those every day expenses of vehicle operation or road maintenance that are taken as a matter of course. The only barrier to the indefinite continuation of this economic waste is the predilection of the engineer to constantly improve his work out of sheer love of doing things as nearly correctly as his working relations will permit.

The following discussion of the economic principles involved in providing highway transportation at the minimum cost must therefore concern itself with both vehicle costs and highway costs.

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The development of highway systems in the United States has reached the stage where some clearly defined method of ascertaining the influence of the various types of roadway surfaces upon transportation costs is needed to assist officials in solving properly a number of questions of administration and finance. It would be particularly helpful in connection with the selection of types of surfacing and the establishment of fair rates of tax imposts on vehicles, where that method is adopted for securing funds for the construction and maintenance of highways.

It is becoming the policy of many highway departments to proceed on the theory that a considerable part of the cost of the construction and maintenance of highways should be borne by vehicles that use them. It often happens that types of roadways are constructed, or old roads continued in service, that require maintenance expenditures in excess of the service value of the roadway surface and therefore place an undue burden on the maintenance funds.

In the past it has been the custom to assume that in general a road surface was worth its first cost, and that the relative values of various classes of highway surfaces were correctly indicated by their relative prices. Now it is beginning to be recognized that price is merely one factor to be considered in comparing types of surfaces, and that the actual value of the surface is dependent upon factors only indirectly related to first cost or contract price.

Value is defined in various ways in dictionaries, and, with reference to its use in the science of valuation, by authors and authorities on valuation. Nearly all of the definitions that appear in treatises on the science of valuation carry the idea that value is related to income producing ability and, since highways do not produce income in the commercial sense, it is necessary to arrive at a somewhat different conception of value as applied to public highways. This may be accomplished by considering that highways are intrinsically valuable because they are an essential element of a service people desire and are willing to pay for. The value of a specific roadway surface depends upon its effect on the cost of transportation. The determination of appropriate improvements for a specific highway and the selection of types of surfaces becomes a problem of evaluating the effect of those improvements on the cost of highway transport.

There is not at present sufficient available information to permit accurate transportation costs to be established but there are fragmentary data that permit of comparisons that are considerably better than outright guesses. When more attention is given to the analysis of highway transportation costs, there will be more systematic cost keeping and the basic data needed will gradually become available.

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Since the highway transportation plant may not be operated for direct profit, its value cannot be based upon ability to produce income but may be expressed in terms of the quantity of transportation service produced per unit of expenditure. Obviously the cost of transport will depend in part on the type of vehicular equipment, but considering the equipment existing in any locality, comparative values for various types of highways in that location may be estimated.

If it be admitted that the value of a highway is measured by the quantity of service it renders per unit of expenditure there remains the need for adopting some measure of this service that will take into account variations in width of highways and density of traffic. British engineers express this quantity in terms of annual cost per sq. yd., per ton of traffic per yard of width, but it appears that a more convenient unit for use in the United States would be annual cost per mile of surface one foot wide, per ton of traffic per foot of width, or more concisely, annual cost per unit of road, per unit of traffic.

A unit of this character presupposes that there is a reasonably definite life tonnage for each type of construction. In any one locality the traffic is reasonably stable in character and it is probably true that for any specific type of construction there is a reasonably definite life tonnage, but since deterioration of a road surface is in part due to the elements and in part due to kind as well as quantity of traffic, that type might not have an identical life tonnage in all localities. It is also probably true that the life tonnage will depend somewhat upon the annual tonnage, since deterioration is in part a function of time. Certain types of roadway surface deteriorate more rapidly if there is no traffic than if there is a reasonable amount of traffic and with nearly all types of pavement surfaces the cost of maintenance per unit of traffic decreases with an increase in traffic, at least up to a certain critical traffic density.

Having determined the vehicle cost per ton-mile for any type of surface and the cost of the highway per ton of traffic, the total cost of highway transport is obtained by adding the two quantities. Since this quantity will vary with the volume and character of the traffic, general tables cannot be prepared, but must be computed for each group of highways of comparable nature. To illustrate the results of such an anlysis Table I has been prepared which is applicable to many highways in the upper Mississippi Valley. Care should be exercised to insure that vehicle operation costs applicable to the locality are used.

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Table No. I.
Total Annual Cost of Transportation in Dollars Per Mile.

(Assuming 90% of tonnage is automobile and 10% truck. 50% of trucks on pneumatic tires, and 50% on solid tires.)

Annual Traffic in Tons	36,000	90,000	180,000	270,000	450,000	640,000
Ordinary Earth	4,672	11,411	22,524	-------	-------	-------
Best Earth	4,520	10,718	21,049	31,328	52,043	-------
Ordinary Gravel	4,761	11,016	21,442	31,868	52,718	126,000
Best Gravel	4,649	10,434	20,056	29,711	48,992	97,182
W. B. Macadam	6,166	12,597	21,171	31,691	51,325	100,319
Bit. Macadam	6,391	12,083	21,413	31,162	49,577	96,507
Sheet Asphalt	5,635	10,951	19,812	28,674	46,393	90,702
Asph. Concrete	5,633	10,947	19,804	28,661	46,373	90,648
Av. P. C. Concrete	5,253	10,563	19,415	28,266	45,967	90,225
Best P. C. Concrete	5,011	9,958	18,204	26,451	42,941	84,173
Vitrified Brick	5,682	10,990	19,843	28,696	46,396	90,648

Editor's Note: A more complete presentation of this subject including several diagrams and tables will be found in an article by Professor Agg in the "Engineering News-Record" of January 10, 1924.

DEVELOPMENT OF HIGHWAY SURFACES.

By C. M. UPHAM,
Chief Engineer, North Carolina Highway Commission.

In North Carolina every attempt has been made to immediately apply the results of research. Almost every step in construction is being studied in detail and when anything of value is discovered, it is immediately applied to construction on a large scale.

Possibly the road that can be considered as the most important in road building and the one that gives the best road service is the one that is termed the development road. A community usually undergoes a rapid development immediately after roads are constructed. In some communities this development does not take place for several years and in others it takes place immediately after the roads are improved. Therefore, the development roads, regardless of what type is selected, must be constructed in such a manner that they may be improved to the next higher step of road construction, so that when the communities develop it is possible to better the road without losing that part of the road that is already constructed. Progressive type roads take care of this feature.

In many states development roads are being constructed largely from local materials. In North Carolina the sand asphalt roads are becoming one of the chief development roads. This road is being constructed in the communities where there is an abundance of sand. A road of this character contains approximately 92 percent sand and 8 percent asphalt; therefore, 92 percent of the road is of local material. This road is being constructed single and double track at a cost of $1.38 per square yard to $1.90 per square yard. Hard surface roads in these communities would cost from $2.80 to $4.50 per square yard. The

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public is receiving a road service at a comparatively low cost and is getting just what it needs for the present.

In another locality in North Carolina, where there is no stone for road aggregate, there is an underlying strata of marl rock. This rock is the result of a large deposit of shells. While this deposit must have at some time been on the seashore, at the present time it is some 8 or 10 miles from the ocean and is about 4 or 5 ft. below the swamp. This marl rock is being quarried and crushed and is furnishing an excellent base for a sand asphalt surface. While the details of this construction were taken from earlier road work, still the use of this marl rock means the practical application of investigative research.

Another important application of research work is in the construction of stone veneer on earth roads. In the south there is an exceptionally large mileage of earth roads, consisting mainly of sand clay, topsoil and gravel types. The bearing power of these roads is high and the strength is great. There is still a great problem surrounding these roads, since they offer very little resistance to abrasion, and have with them the dust problem as well. Thus, the problem in this particular instance is to secure some means of protecting the surface against abrasion and to abate the dust nuisance. This seems to have been found in the stone veneer surface where the quality of an asphalt wearing surface is combined with the strength of an earth road. There have been several attempts made in applying bituminous material to earth roads. These in general have been unsuccessful, due to the fact that if the bituminous material was sufficiently light to penetrate the surface, it had no binding power or strength whatever, and if the bituminous material was sufficiently heavy to have a binding value, it would congeal on the surface and peel off, due to the fact that a dust mat was formed underneath the bituminous material. This problem seems to have been answered by applying a layer of stone of approximately 3 inches in size to the earth road surface and rolling it partly into the surface, after the surface has been scarified or loosened; and then penetrating the top of the stone with bituminous material of a consistency to give sufficient strength to hold the material in place and afford resistance to wear. This bituminous material is then covered with proper sized stone and rolled and opened to traffic. The stone is held in place from below by the earth road and has become an integral part of it. The bituminous material holds the stone in place on the surface and affords a resistance to traffic abrasion. Thus, we have a combination of the strength of an earth road and the wearing qualities of an asphalt pavement. This again is the practical application of research work.

Editor's Note: A more extensive discussion of this subject will be found in an article by Mr. Upham in "Engineering and Contracting" issue of January 2, 1924.

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ECONOMY TO THE PUBLIC OF GOOD HIGHWAY MAINTENANCE.

By S. C. HADDEN,
Secretary, Allied Motor Commerce of Indiana.

In a discussion of the economy to the public of good highway maintenance it is inevitable that some figures be quoted. That it costs less to propel a vehicle of any kind over a good road than over a poor one is an elemental truth. It is so self-evident that any man will admit it without argument and then proceed to forget about it, or ignore it, or act as if he never heard or thought of it. He admits the truth but is likely to resist its application. It is to the latter phase of the matter that special attention will be given by the present speaker. The first figures given will show the economy to the public in maintaining a good highway as compared with a fair one or a poor one.

Probably every man here operates a motor vehicle. All have observed that gas and oil go further on good roads than on bad and the same is true of tires. Just a few days ago a bus owner gave me some interesting figures on tire performance on concrete and gravel roads. He operates a bus line from Indianapolis to Richmond and another between Indianapolis and Bloomington. On the Richmond line he operates units made up of a 2½-ton G. M. C. truck chassis with heavy bus body. On the Bloomington line he uses Studebaker 7-passenger touring cars. He uses the same size and make of cord tires on the rear wheels of the touring car as on the rear wheels of the truck. On the Richmond run, which is entirely over concrete roads, these tires are good for 28,000 miles. On the Bloomington run, which is all gravel, he never gets over 12,000 miles. Here is a case where all other factors affecting tire deterioration have been eliminated because of the rapidity of the wear due to intensive service and the concrete road is giving more than double the tire mileage of a first class gravel road. I have had other figures on the saving of tires by hard surfaced roads which are in close agreement with those here given.

When it comes to saving in gasoline, tests have shown that with gasoline at 24c a gallon, the cost of gasoline per ton mile on a dirt road is 1.71c, on gravel is 1.15c and on concrete 0.77c. Another way to state the comparison involving gasoline consumption on these three types of road is that concrete gives 31 ton-miles per gallon, gravel 21 ton-miles and dirt 14 ton-miles.

At a time when road building is going forward more rapidly than ever before in the world's history it may seem strange to many to speak of highway development as lagging, but that it

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is lagging behind the development of the agency that called it into being, namely, the motor vehicle, can easily be shown. There is small danger that we will build modern highways too fast, but there is real danger that the present rate will not be sustained unless the people are made to realize that it is cheaper to have good roads than poor ones.

Mr. Thomas H. MacDonald, Chief of the U. S. Bureau of Public Roads, whose great ability more than out-matches the duties of his high office, recently formulated this fundamental principle: "Lack of a complete trunk line highway system is a greater economic cost to the public than the cost of constructing it." He also said: "Until a state has completed the backbone of its trunk line system with suitable paved or surfaced highways, the rate of construction should be independent of the source of the revenue or the method of payment for the work. For the use of the principal highways is so extensive that the people pay for adequate highways whether they have them or not, and they pay less if they have them than if they have them not." This is, undoubtedly, true but the general public has not thought of the matter in this light.

That we are not now spending anything like as much on rural highways, per motor vehicle in operation, as we did in the year 1904, is a matter of record. In 1904 there were, in the entire country barely 58,000 motor vehicles and these were nearly all passenger cars. In 1914 this figure had increased to 1,711,399; in 1919 it was 7,530,105 and in 1923 reached approximately 14,000,000 motor vehicles. Now compare the rural highway expenditures for the same years: 1904, $59,527,000; 1914, $240,264,000; 1919, $389,456,000; 1923, $800,000,000. Thus it will be seen that the rural highway expenditure per motor vehicle in operation in 1904 was $1,026; in 1914, $140; in 1919, $52 and in 1923, $57. This expenditure in 1923 was only 5 per cent of what it was in 1904.

The 14,000,000 motor vehicles in operation at the end of 1923 represented a purely voluntary investment by the American people of at least ten billion dollars. The cost of operating these vehicles in 1923, on the basis of an average mileage of 4,000 at 10c per mile, was $5,600,000,000. Now if we can save just 1c per vehicle, per mile, by improving our roads, and this can be done, we would save $560,000,000 each year, on the number of cars in use in 1923. Of course this saving will increase as the number of cars increases. Even this figure, capitalized at 4½ per cent would justify an investment of $12,500,000,000.

It is always good business to spend money to save it. The railways have often spent large sums of money to rectify line and grade, for example, in order to save on operating expenses. Every motor vehicle owner is in the transportation business:

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the business of transporting himself, if nothing else. He can be made to see that his annual investment in transportation will grow progressively less from year to year as the roads he uses are improved.

The people of Indiana have been deliberately, systematically and persistently misled and mis-educated with respect to motor vehicle license fees. For years these fees were far too low; so low as to keep the State Highway Department poor and unable to keep up with its Federal Aid. The new law brings these fees up to where they are in other states and will, if held valid, enable Indiana to move forward with her program of highway improvement. It should be evident to everybody that since Indiana cannot bond for State highways we must finance these highways largely out of motor vehicle license and gasoline fees. The State Highway system should be the first concern of all of us for we are, first of all, citizens of Indiana and only secondarily are we county, township, or city officials, educators or business men. We should test every proposal of highway finance first by this criterion: "will it rob the State Highway Department?" If so, the proposal, however excellent otherwise, needs modification in this particular.

And, finally, maintain means "to carry on without interruption." That is what we must do in this highway movement for it is false economy to save money on roads and put it into vehicle operating expenses. The people must be made to see this is not a fad, or even a matter of convenience and comfort, but is a clean-cut business proposition.

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THE PRESENT AND FUTURE INDIANA STATE HIGHWAY SYSTEM.

By EARL CRAWFORD,
Commissioner, Indiana State Highway Commission.

Mr. Crawford gave a splendid resume of the past, present and future work of the state highway department. The following points are taken from the editor's notes as the speaker did not present a paper.—Editor.

Many of our state roads were created by legislative acts during the period of 1821 to 1840. About all the state did was to fix the width and clear the right-of-way. All repairs were made by local farmers. For many years we worked under the system of permitting the farmers to work out the road tax. This system has proved to be an absolute failure, especially since the advent of the automobile.

In 1917 a law was passed creating a state highway commission, but it was held up two years by a test suit. In 1919 this law was repealed and a new one passed under which we are working at present. The law provides that the commission shall lay out a system of state roads touching every county seat and all towns of 5,000 population or over. But we have gone farther and our system now reaches every town in the state of 2,500 population or over with the exceptions of Gas City, Dunkirk and Nappanee.

At the present time there are 4,100 miles of road in the state system. Eventually this will be increased, (as funds are available), to approximately 5,000 miles to comply with the Federal Aid law specifying that each state must take over seven percent of its entire road mileage as a state system.

About 800 miles of our state roads are now paved. Our program, based on increased revenue from gasoline tax and auto license fees, provides for increasing this total to 1,500 miles by the end of 1925. This is two percent of the total road mileage in Indiana and will reach 66 counties, serving 50 percent of the state population.

Indiana has approximately 72,000 miles of roads of which 39,000 miles are improved. This is the greatest mileage of improved roads of any state in the U. S.

Federal Aid funds are provided to help construct and reconstruct approved roads in state systems. By the end of 1925 we will have $6,000,000 of Federal Aid money available which we will match with state funds to complete our two-year program. Indiana is receiving Federal Aid at the rate of about $2,000,000 a year.

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RECORDS AND ACCOUNTS OF COUNTY OFFICIALS.

By LAWRENCE F. ORR,
State Examiner, Indiana State Board of Accounts.

Through the installation of a uniform system of accounting in Indiana which was first undertaken in 1910 by the State Board of Accounts under the provisions of the Public Accounting Law, and by the revision of certain forms from time to time, many thousands of dollars have been saved to the tax payers of the state. Prior to this, careless and crude methods of every sort were in use, and in some places the officials' individual check book and bank pass book were the only records kept for the transaction of official business. In some instances certain officials in smaller places would rely entirely on their memory in order to make reports of their affairs at certain periods.

One of the main functions of the State Board of Accounts has been the installation of uniform records, and compelling the use of same. However, it might be said in this connection that public officials as a general rule have willingly co-operated with the Board in keeping such prescribed records.

Through the period of 13 years which has elapsed since the installation of the forms prescribed, revision of certain forms and parts of same have been made when the occasion demanded. We have now come to a point where it is necessary that all forms of records be carefully studied by our department with a view of complete revision to suit modern methods of accounting and simplifying the manner of keeping such accounts.

Our purpose in undertaking this complete revision is not only to provide an up-to-date, clear, and efficient system but to expedite the work of the public officials, which in many instances has increased materially in the last 10 years. It is our object to make the accounting system of all offices produce the same results as now required, without losing sight of any detail; but nevertheless to simplify the matter of keeping such records in order that the accounts will be an open book to the public and that the public may not be bewildered by any complex system of reckoning which may leave them in the dark as to whether or not their money has been properly expended.

New forms of accounting were prescribed about a year ago for the office of the Highway Superintendent. We have found as a general rule that these forms meet with the approval of the superintendents of the state as well as with the approval of the county auditors and boards of county commissioners. They afford a true, complete, and exact record of affairs when the system is carried out entirely as prescribed. These forms not only

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provide a systematic method of accounting, but are a safe-guard for the Assistant Highway Superintendents, the Highway Superintendent, County Auditor, and Boards of County Commissioners in administering their duties pertaining to the repair of free gravel and improved roads of the county.

I want to urge that the Highway Superintendent in making his annual estimate of expenses pertaining to the repair of roads for the ensuing year, should take into consideration carefully all things necessary therefore, so that the tax levy can properly be made and proper funds sufficient to carry out the year's program be appropriated. Due sometimes to overlooking certain necessities that are sure to arise during the year, or with a view of not facing these things until they actually occur, the estimates have not been properly made, and the fund is depleted, causing many claims to be presented which cannot be paid, resulting in embarrassment for the Highway Superintendent, County Auditor, and County Commissioners, and causing a situation which is hard to explain to local tax payers. Under the provisions of the statutes, no over-drafts can legally be incurred. The legislature is then called upon to legalize and authorize the borrowing of money to pay these claims which have accumulated due to lack of funds for the repair of the improved roads of the county. If proper estimates are made, such conditions as a rule would be generally prevented. The Highway Superintendent and his Assistants by being particular in administering the duties of their offices can perform efficient services in their communities, and if due economy is used, they can keep the roads in condition contemplated by the statutes, and to the best interests of the taxpayers and traveling public.

Law Governing Expenditures of Road Funds.

It might be well at this point to call attention to certain provisions of the statute relative to the repair of gravel roads and the duties of the Superintendents. The law provides that annually, at least 30 days before the road levy is fixed for the road repair fund, the County Highway Superintendent shall file with the Commissioners a report disclosing the ways and means which in his judgment should be employed during the coming year in order to take care of the roads under his supervision to the best advantage. This report shall include an estimate of machinery, implements, transportation facilities, road material or other equipment that may be needed to maintain properly the roads under his supervision for the ensuing year. The law further provides that the Board of County Commissioners shall give such report their careful consideration and either approve or alter and approve same, and recommend to the County Council a sufficient levy for the coming year so as to provide funds

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which shall be used to carry out the provisions specified in said report. In the matter of repair of bridges and culverts, the Superintendent shall make no expenditure for such purposes in excess of $50.00 without the approval of the Board of County Commissioners. Whenever an expenditure of more than $100.00 is necessary for any bridge or culvert, same shall be expended as heretofore provided by law. Since the statute requires that such expenditure be made "as heretofore provided by law," such expense should be paid from the appropriation for bridge repair of county revenue wherever same shall exceed $100.00; otherwise, from the gravel road repair fund, and contracts therefore shall be let upon competitive bidding.

In the matter of the purchase of road and bridge repair material, and for tools and machinery necessary, the statute states same shall be purchased in the manner provided by law. In referring to contract to be made "in the manner provided by law," the statute contemplates that purchases shall be made upon competitive bidding only. It is not necessary that specific appropriations be made from the free gravel road repair fund for the purpose of entering into contract for the purchase of certain material, machinery and tools, since the fund itself is a specific fund provided for by statute, to be used for a specific purpose, viz: repair and maintenance of the improved roads of the county. However, it is necessary that contract should be made upon competitive bidding in making such purchases, since the statute clearly provides that same must be done in accordance with the manner provided by law.

In case a petition has been filed with the County Commissioners asking for the improving of a township road, and the County Commissioners have finally granted such petition and made an order of record that the road be established, the up-keep of same is then with the county and not the township, pending the letting of contract and issuing of bonds for such improvements.

If certain streets in a city or incorporated town have been constructed by the Board of County Commissioners under the provisions of the statute providing for the construction of such improved roads by taxation of property by such township containing such city or town, including the property within such city or town, and necessary repairs are made by such city or town, the cost of such repairs is to be paid by the county from the free gravel road repair fund.

Claims duly verified should be filed with the county Auditor, such claims to be fully itemized as provided by the statute. The statute makes it mandatory upon the county, to pay for such repairs made by such city or town.

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Inventory of Equipment.

It is our further aim to make a public office more of a business institution, and to that end we will recommend that all officials who have charge of any public property should keep a complete inventory of same. The total expense of county government when considered merely as expense, often-times seems very large, but if something tangible can be shown for such expenditures, or a part of same, in the way of machinery, equipment, tools, supplies on hand, and buildings and land purchased, we will then have something in lieu of money so expended. In other words, the total expended may be decreased by these assets and the net amount will be the sum for which nothing tangible remains but nevertheless represents the true running expenses and maintenance cost of operating the county's business. The keeping of such an inventory we regard as good business, and we regret to state that such a method has not been pursued to any extent in the state.

Under present conditions it is very easy for a typewriter to disappear (I do not mean the stenographer) in an office where there are several in use, or a quantity of supplies for the office may take leave of absence. Even in your own departments various tools or even machinery may be lost unless a proper inventory is kept showing the equipment owned that is in use, and how and where same is disposed of from time to time. Without such an inventory throughout the institutions, departments and offices, no county can know its true worth in the matter of public property owned. This same condition also applies to townships and various corporations of the state, as well as to some departments of state government. I have no doubt thousands of dollars have been lost to the public by lax methods and carelessness in keeping a watchful eye on the public property.

Our department is already studying these conditions and will install and prescribe proper forms for inventories and reporting upon such property, just as soon as possible. We believe such a step will be in the direction of the more proper administering of public offices by those who have been chosen by the people to represent them in their public affairs.

We believe that a close study of office methods generally in these offices and departments will result in a great deal of good and in a saving of a large amount of public funds. Our aim is not to criticize in these things, but we believe that in the administering of the Accounting Law in the matter of supervision and inspection of public offices we should do all things possible in the interest of the public. We desire to be courteous in our treatment of public officials and seek the co-operation of such officials in the discharge of their official duties in a businesslike and careful manner.

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The State Board of Accounts through the Department of Inspection and Supervision of public offices, has duties of vast importance to perform for the public and the most important of these are as follows:

1. Examination of all public offices, town boards, institutions and departments of state, county, township, city and town governments, making in all more than 5,000 examinations to be made annually.
2. Examination of public contracts upon petition therefore in order to ascertain whether the contractor has carried out and complied with the terms of his contract and the plans and specifications.
3. Examination of plans and specifications of public buildings, in order to ascertain whether same provide for free and open competition among bidders.
4. Prescribing and installing of uniform records in public offices and compelling use of same.
5. Extending of timely advice to public officials in the matter of the provisions of the statute pertaining to their offices upon the theory that "an ounce of prevention is worth a pound of cure."

These are all functions of the most importance and vital to the public, and must be administered in strict compliance with the statute and the purpose for which the Legislature intended, in passing the Public Accounting Law.

In the examination of public funds, the Legislature wisely provided that such examination should be made annually. Where examinations are delayed, the official sometimes becomes careless and errors creep into his work requiring much more time to be spent by examiners than if only one year's work were to be audited and examined.

We are using our best endeavors to bring up the work so that examinations can be made every year. Any attempt by the Legislature to limit the Board of Accounts in its examinations, to the making of same at the end of a term of an official instead of annually, will be a backward step and will cripple the administering of the public accounting law. If such an official desired to be dishonest, he could not only withhold funds from the depository and use same to his own personal advantage, but would have every opportunity to make a "get away" before examiners could complete their work, if examinations were to be delayed until the end of his term. Annual supervision not only has a repressive effect upon an official who is unscrupulous, but it is a source of help and assistance to the official who desires to administer the affairs of his office in a conscientious painstaking

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manner. However, I desire to state that most officials are honest and desire to be faithful to the trust imposed upon them.

A business concern will require audits to be made of its affairs at stated periods and does not for a moment consider waiting until its head bookkeeper or auditor leaves the company before making an audit and investigation of his accounts.

Examinations of Contracts.

The department has before it many petitions alleging that public work has not been performed according to plans and specifications. Such petitions have been filed pursuant to the provisions of the 1923 Act, which is supplemental to the original Public Accounting Law. Since the act became effective March 7, 1923, we have through examinations and reporting upon such contracts and by means of court decisions supporting our findings, caused a saving of $60,000 to the taxpayers of the state. These figures apply only to those cases which have been settled.

There are many others which are now pending on our records and in course of settlement. Three typical examples may be cited as follows:

1. A contract was awarded by a certain town for the construction of a sewer at an approximate cost of $104,000.00. The report of our Examiner upon this contract showed that catch basins were not constructed in accordance with the plans and specifications, in that said basins had not been plastered as required. House connections with said sewer were constructed in a way as to prevent the flow of water from the house.

   It appears that proper excavation was made at the house and at the point of connection with the main sewer, but between these points it was found that the sewer was not placed at a proper depth thereby permitting the sewer to be much higher near the middle than it was at each end.

   It was found that it would require $9,661.24 to complete this contract in accordance with the plans and specifications. It was admitted to this department by the contractor that the estimate of the amount required, made by our engineer, was approximately correct.

2. In a certain town a contract was awarded in 1923 for the improvement of seven streets, using a concrete base covered with asphalt, at an approximate cost of $170,000.00.

   Under the specifications the concrete was supposed to be a thickness of 5 inches and the asphalt 2 inches. After the concrete base had been finished in all the streets and most of the

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asphalt laid, this department was petitioned to make investigation and examination of the improvements, to determine if there had been a compliance with the specifications, by the contractor. It was found that the concrete was improperly mixed and was not the required thickness in many places by from 1 inch to 2¼ inches, and in many instances was so soft that water which had fallen the night before our investigation, had penetrated thru and was standing on the sub-grade. Catch basins were improperly constructed in that they had not been built to their required dimensions. Curbing was placed on clay soil with no foundation whatever. It was further shown that the asphalt was not of a proper mixture. This case is now in court, and a decision will be given later.

3. A contract for the improvement of certain streets in another town was awarded at an approximate cost of $40,000.00. Our examiners found this improvement was not constructed in accordance with the plans and specifications, and the property owners brought an action against the contractor and the town board, and the court found that the contractor had completed only 65% of his contract and rendered judgment accordingly.

In each of the foregoing instances the engineer of the municipality, and the inspector in charge, as well as the contractor, had made their sworn statement that the work had been done in accordance with the plans and specifications.

The statutes provide that our department shall make such investigations upon the petition of 25 or more taxpayers alleging that local relief has not and cannot be obtained. In some cases we are not able to make the examinations where there is complaint, owing to the fact that there are less than 25 taxpayers affected by such improvement. This situation exists in the case of certain street improvements in cities and towns. The statute should be remedied in this regard.

The Act should also provide for such inspection upon the request of officials who have jurisdiction over such public work, since many times such officials prefer that examination be made and do not desire to circulate a petition, or if they do circulate such petition are unable to obtain sufficient signatures to cause an investigation.

In the extending of advice to public officials, we have cited the laws in thousands of instances and thereby placed officials on the right track in the pursuit of the duties pertaining to their offices. Those who have been willing to follow the provisions of the statute have acted accordingly. In some instances officials have taken certain fees and allowances of which they were either in doubt as to their legality, or else were aware that such allowances were contrary to law.

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If an officer has obtained allowances illegally, or expended funds illegally, our department has no authority, in view of the statutes, to release him from any illegal action. Political influences will have no bearing in such cases. The statute must be followed. If it is fair to release one officer on the charge of illegal procedure, it is fair to do so by others who have followed a like course. If our department condones such things, the very foundation of the public accounting law will be destroyed and it might as well cease to function.

Examination of accounts and reporting on same must be kept free from any political influences. The Board must pursue its course on a business-like basis. It is vital that the citizens of the state should have faith in the State Board of Accounts, and its affairs must be administered in an honest, careful, prudent and conscientious manner.

SAFETY AND UTILITY FACTORS AT RAILROAD CROSSINGS OF ROADS AND STREETS.

By L. F. SHEDD,
Superintendent of Safety, C. R. I. & P. R. R. Co.

Mr Shedd's talk was highly interesting and instructive. Since he did not present a paper we are only able to print a few notes jotted down as he was talking.—Editor.

Considerably more fatalities occur in railroad crossing accidents than in accidents or wrecks on trains themselves. During the year of 1922, on one-half of the railroad mileage in the U. S. there was not a single fatality among the passengers. This is remarkable when we consider that we have approximately 265,000 miles of railroads.

There are, in round numbers, 250,000 grade crossings, or approximately one to every mile of R. R. line. A very conservative estimate of the average cost of eliminating these crossings is $50,000. This accounts for the slow progress of grade separation, although a large number of the more dangerous grade crossings are eliminated each year.

With the coming of the automobile, crossing accidents have been enormously increased. In a big percentage of the cases the driver is directly responsible, due to absolute disregard of stationary signals, mechanical warnings and even crossing watchmen. In a total of 207 crossing accidents on the N. Y. C. R. R., 70 per cent occurred at open crossings where the view was unobstructed.

The railroads stand ready to co-operate in reasonable methods of reducing these accidents. However, the drivers themselves must carry a great share of the responsibility.

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SIGNS, GUARD FENCES, AND CROSSINGS.

By JAMES L. TUCKER,
Clay County Highway Superintendent.

The great evolution in modern traffic and travel has made these three items of most vital importance. "Safety first" is the slogan the world over. Danger is the bane of the highway today and must be eliminated. Last year, according to reports, approximately 15,500 persons lost their lives in automobile accidents and probably three times that many were injured. To this, add the heartaches and privation and increased taxes and property loss, and you have a sum totalling such a gigantic figure that we begin to wonder if the advantages are worth the price we pay. Remember, too, that this is only in its infancy, that it is increasing in almost geometrical progression and I shudder to think what the result will be unless we take radical steps to eliminate danger. Three things evidently must be done, viz: we must warn the public by posting proper notices; drivers must be educated to realize their responsibilities and heed the danger: drastic laws must be enforced against offenders.

I heard a story of a young man who took his best girl to the fair. Being short of money and noticing a vendor's sign which read, "Ice cream $2 a gal.", he remarked, "Law me, Sue, if it takes as much for a feller as it does for a gal., we'd better let ice cream alone and stick to lemonade." Some people are about as ignorant in reading danger signs. Some are so possessed of the dare-devil spirit that they would rush pell mell into danger, even if a Demosthenes or a Cicero were shouting warnings into their ear with a megaphone. Some way must be found to deal with this class of offenders. They must neither be allowed to commit suicide, nor endanger the lives of law abiding citizens, who, contrary to their opinion, have a perfect right to travel the public highway in safety.

I had thought that the law of the survival of the fittest might operate in this case, but it doesn't seem to do so. When I meet a saphead driving fifty miles an hour around a dangerous bend and I am forced into the ditch to protect my life and flivver, I am rather disposed to frown on the theory of evolution in general and Darwin in particular. The strong arm of the law must be invoked to curb this class of offenders, and the sooner we force the bit into their mouths the better it will be for all concerned. I saw a report recently in a highway magazine, where out of 1909 accidents on one railway system 409 automobiles ran directly into the train and 122 broke through the crossing gates. Most of these accidents can be attributed to reckless driving.

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While signs are disregarded by some drivers, I strongly favor their erection and the erection of guide posts in giving directions and distances to important points. I am strongly in favor of their being placed by men who are authorized to do this and may be held responsible. It is high time that counties take this matter entirely into their own hands, instead of leaving it to unscrupulous dealers and business men who have no other purpose in erecting them than advertising their wares or directing the motorist to a place to have his flivver mended. They erect them at the most conspicuous points to catch the eye of the public, and many of them where there is no danger whatever, often resulting in serious accidents by causing drivers to disregard signs which are correctly placed. The old adage, "The truth itself is not believed from one who often has deceived," is applicable here.

A notable improvement in beautifying the roadside has been started near the village of Riley, in Vigo county, whert a beautiful pavement crosses an artistic bridge over Honey Creek, following the line of the old Louisville Road with its graceful curves. Guard rails have been erected for a distance of more than one-fourth mile and painted white. An organization of ladies has planted climbing roses near each post. This will be one of the beauty spots of the country when the roses attain maturity and are laden with their wealth of bloom. Thousands of like places can be found in Indiana, where with very little expense and care, an otherwise dismal spot could be transformed into "A thing of beauty that would be a joy forever."

A story is told of a French boy who had his servant awake him every morning with the words, "Arise, Monsieur, you have great things to do today." Highway superintendents and road officials have a great responsibility. They are going to leave their stamp upon their county, state, and nation just in proportion to the effort they put forth to make each dollar of the taxpayers' money count to produce the desired result. That result is not alone to build serviceable roads and maintain them, but to bring about conditions that will be safe for your family and mine and all others to travel the public highway without the continual nightmare of an impending calamity. It is also to help beautify "these little brown roads of Indiana," so that they may add much to the happiness of our own people and the stranger that is within our gates.

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SPECIFICATIONS.

By Ben H. Petty, Asst. Prof. of
Highway Engineering, Purdue University.

In considering a set of specifications it must be borne in mind that there are three parties involved, namely, the buyer, the contractor and the engineer. Most troubles over specifications are the result of each of these parties perisisting in interpreting them according to his own particular viewpoint without regard to the rights and considerations of the others. It has been said that the great confusion of tongues and resulting failure in the building of the Tower of Babel was probably caused by a disagreement over specifications. Specifications should be so written that the buyer, (the taxpaper in the case of public improvements), gets what he pays for and pays for what he gets.

It usually falls to the lot of the engineer to write up the specifications for various types of construction work. The writer should critically analyze his specifications, first as the buyer, then as engineer and finally as contractor. Viewed carefully from these three viewpoints, the specifications can be so shaped that they will adequately safeguard the interests of all parties concerned.

Specifications are interpreted primarily by the inspector and the contractor. The average inspector, especially on public work where politics has a free rein, is absolutely incapable of properly discharging the duties with which he has been intrusted. In many cases he knows practically nothing about engineering, frequently being unable to read a blueprint. It is little wonder that construction under such poor supervision often results in failure. But, on the other hand, construction projects free from political contamination frequently move along under very incompetent inspection due to the very poor salaries paid for this work. On the average highway job, for instance, it is practically impossible to induce a man with the necessary training and experience to accept a position as inspector at the low salaries offered, from $90 to $150 per month.

In my opinion, the inspector is one of the most important men on any construction job, if not **the** most important. Regardless of the reputation and ability of the engineer or the excellence of the specifications, nine times out of ten the structure will be made or marred by the ability of the inspector. Millions of dollars of the taxpayers' money are wasted every year as a result of economizing on inspector's salaries.

Recently I spent a day on a county macadam road job a little over a mile in length. The inspector was a young, local farmer, apparently honest and well meaning but absolutely ignorant as far as his duties were concerned. Only center-line

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grade stakes had been set and as soon as the first layer was removed from cuts and first dumping made in fills, these stakes were gone and there was no way of telling whether the grading was correct or not. I asked the inspector how he knew whether or not the grading was finished to specifications. He said he had gone over the line of stakes before the work started, noting the cut or fill marked on the various stakes and had "sort of estimated" where that elevation would be on the fence along side. Imagine the results from such a method. And there was no fence along about half of the road. The road was never finished according to specifications and the case hung fire in the courts for many months. Considering the money lost by the county on this job, they could easily have paid a capable inspector ten, fifteen or even twenty-five dollars a day and still have been ahead financially as well as having the kind of road they ordered.

Specifications should be interpreted upon the broad grounds of professional intelligence as well as common sense. Unforseen difficulties will arise on almost every job, requiring certain variation from the letter of the specifications. Inexperienced inspectors are prone to stick absolutely to the wording of the specifications in such cases thereby precipitating a battle with the contractor and in many cases obtaining results wholly contrary to the desires of the one who wrote the specifications.

The authority of the inspector should be clearly outlined, (mainly for the benefit of the contractor), and he should be relieved as much as possible from errors of judgment resulting from the too frequent use of the clause, "to the satisfaction of the engineer."

I do not favor the arbitration clause in specifications. In case of disagreement between contractor and engineer, the latter should be the final authority. Arbitration spells compromise in practically every case. The engineer writes the specifications to get for the buyer what he pays for. Usually a compromise does not attain this desired aim.

Copying specifications too freely is a dangerous habit frequently indulged in by incompetent engineers. Many counties possess highway specifications that have been copied blindly from various sources. Many of them were obsolete when copied and have never been revised. As a result they are worthless. It is always dangerous to copy highway specifications that are four or five years old because the designs, methods, etc., are changing so rapidly. The revolution of the design of concrete slabs resulting from knowledge gained in the Pittsburgh, Arlington and Bates Road tests may be sighted as an example.

The standardization of paving brick, asphaltic materials, concrete mixers, etc., brought about by the Department of Commerce under the direction of Mr. Herbert Hoover, (himself an engineer), has greatly simplified the work of the highway specification writer.

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PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE.

BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright, 1922.

CIRCULAR No. 1. Care of Roads During the Spring Break-up. by Ben H. Petty, 1923 (out of print).

BULLETIN No. 2. House Construction that Reduces Heating Costs. by James D. Hoffman, 1923.

BULLETIN No. 3. Pictorial Description of Engineering Activities, Purdue University, 1923.

BULLETIN No. 4. Electric House Pumping Systems, by G. C. Blalock and D. D. Ewing, 1923.

CIRCLAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

BULLETIN No. 5. Proceedings of the Tenth Annual Road School, by Ben H. Petty, 1924.

The following material has been issued in mimeograph form:

FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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BULLETIN OF
PURDUE UNIVERSITY
PUBLICATIONS OF THE ENGINEERING DEPARTMENTS
VOL. VIII NO. 6

Proceedings
of
Second Annual Conference Indiana Foundrymen
held at
Purdue University

J. P. WALSTED

BULLETIN NO. 6
ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

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THE ENGINEERING EXTENSION SERVICE OF PURDUE UNIVERSITY

Purdue University recognizes its opportunity for public service by carrying the benefits of its teaching and research activities to those in the State who are interested in engineering problems, but who are unable to be benefited by the regular courses of resident instruction which are offered at the University.

The Engineering Extension Service of Purdue University is carried on in the following ways:

1. Conferences are held at Purdue University and at other places in Indiana for the benefit of road builders, canners, electrical workers, power plant men, foundrymen and for others engaged in manufacturing and in public utility industries.

2. Groups of lectures are delivered by engineering experts of Purdue University for the benefit of industrial workers and executives. Talks are also given on subjects related to engineering before civic, commercial and manufacturing organizations.

3. Publications in the form of bulletins and circulars are issued containing up-to-date information on engineering subjects.

Address communications concerning Engineering Extension Service to

DIRECTOR OF ENGINEERING EXTENSION SERVICE,
Purdue University, LaFayette, Indiana

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BULLETIN NO. 6
ENGINEERING EXTENSION SERVICE

Proceedings

of

Second Annual Conference Indiana Foundrymen

held at

Purdue University

Held under the direction of the
Department of Practical Mechanics

Indiana Foundrymen's Association
cooperating

Compiled and Edited by
J. P. WALSTED
Research Assistant, Engineering Experiment Station

PURDUE UNIVERSITY
LAFAYETTE, INDIANA

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FOREWORD

The Engineering Extension Service of Purdue University, from time to time, holds conferences to bring together the men engaged in the various engineering activities in the State of Indiana. The Conference of Foundrymen held on January 17 and 18, 1924, was the second of its kind. Professor J. D. Hoffman, head of the Department of Practical Mechanics, under whose direction the conference was held, spared no effort in the arrangement of a complete and interesting program. By his efforts, the best speakers obtainable were placed on the program. The topics taken up were on such a wide variety of subjects that all who attended obtained something of value from the conference.

A. A. POTTER,
Dean of the Schools of Engineering and
Director Engineering Extension Service.

REPORT OF SECOND ANNUAL CONFERENCE OF INDIANA FOUNDRYMEN

Held at Purdue University January 17-18, 1924

A conference of the foundrymen of the State is held each year for the purpose of discussing problems of interest to the foundry industry.

Papers are read at these meetings and are followed by general discussion. In this way much valuable information is gained by those attending.

Subjects covered in these papers include: the training of apprentices; casting of steel, semi-steel, cast iron and non-ferrous metals; metallurgy and general foundry practice. In fact, any subject of importance to any branch of the cast metal industry may properly be discussed at these meetings.

Incidental to this second conference is the meeting of the Indiana Foundrymen's Association which was organized in November, 1922.

The following pages give a fairly complete extract of each paper read at the conference and also a brief statement concerning each speaker.

J. D. HOFFMAN,
Professor of Practical Mechanics.

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PROGRAM

All Sessions will be held in Room 101, Michael Golden Shops

THURSDAY, JANUARY 17

9:00-10:30 a. m.—Registration in Michael Golden Shops.

10:30-12:00 a. m.—Visit to various Engineering Laboratories.

12:00 m.—Luncheon at the Home Economics Building, Purdue University.

Afternoon

Presiding—W. A. Knapp, Assistant Director Engineering Extension Service.

1:15 p. m.—Address of Welcome—
A. A. Potter, Dean of Engineering, Purdue University.

Response—
W. D. Hammerstadt, President, Indiana Foundrymen's Association.

1:45 p. m.—Selective Training for Foundry Work, R. E. Wendt, Instructor in Foundry, Purdue University.

Foundry Foreman as a Teacher, G. F. Buxton, Ass't Professor Industrial Education, Purdue University.

2:30 p. m.—Metallurgy in Gray Cast Iron, E. J. Lowry, Hickman, Williams & Co., Chicago, Ill.

3:30 p. m.—Manufacture of Steel Castings, Wm. Woodhall, National Car Coupler Co., Attica, Ind.

4:30 p. m.—Making of Semi-Steel Castings, G. W. Gilderman, Dodge Mfg. Co., Mishawaka, Ind.

Thursday Evening

Presiding—W. D. Hammerstadt, Rockwood Mfg. Co., Indianapolis, Ind.

7:30 p. m.—Meeting of Indiana Foundrymen's Association and Smoker, Michael Golden Shops.

FRIDAY, JANUARY 18

Forenoon

Presiding—J. D. Hoffman, Head of Department of Practical Mechanics.

9:00 a. m.—Electric Furnace Product in the Foundry, W. K. Booth, Booth Electric Furnace Co., Chicago, Ill.

10:00 a. m.—Non-Ferrous Metals, E. G. Jarvis, Niagara Falls Smelting and Refining Co., Buffalo, N. Y.

11:00 a. m.—Production Work Motion Pictures, The Beardsley & Piper Co., Chicago, Ill.

Afternoon

1:30 p. m.—Demonstration Heat by the Use of the Electric Melting Furnace.

2:00 p. m.—Gray Iron Heat in the University Foundry by students in regular class exercise.

3:00 p. m.—Visit of Inspection to Shops.

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SELECTIVE TRAINING FOR FOUNDRY WORK

R. E. Wendt

Mr. Robert E. Wendt is a practical foundryman of many years experience. Mr. Wendt's wide experience in commercial work, both as a practical molder and as a teacher of apprentices, coupled with his experience in teaching foundry work at Purdue University, makes him eminently fitted to discuss the question of apprentice training.

An important problem in the foundry industry today is the securing and retaining of the right kind of help. A few foundries are able to obtain all the trained men needed, but the ones who are able to do so are relatively few. Nearly every trade paper devoted to the foundry industry gives some space to the discussion of the problem of obtaining skilled mechanics. The situation is more serious than many are willing to admit. Those who are interested in the foundry business must take up the problem of training more foundry men, not only to relieve the present situation, but also to provide for the future.

There is among foundrymen today a variety of opinion regarding this problem. One group claims that the old system of apprenticeship must be re-established. Others state with equal conviction that in this age of machine methods, fewer foundrymen are needed. Still others claim that it is impossible to get young men to take up foundry work. None of these claims are based upon good logic, as will be seen when they are more carefully studied.

First let us consider the apprenticeship system. This system would be entirely inadequate at this time. The right kind of men would not be attracted by such a plan of development for the reason that the goal is too obscure. There are other lines of endeavor which promise definite returns in a shorter time and with less effort. Moreover this system is wasteful. Every young man who becomes disgusted and leaves his apprenticeship before completion represents a distinct loss to the industry and to the company that has spent time and money on his training. Perhaps very few foundrymen would be willing to return to the old apprenticeship system with its attendant evils.

The claim that not many foundrymen are needed is far from true. Perhaps fewer all-around molders and core makers are needed than formerly, but even with the advent of molding and coremaking machines, we need not only as many but more and better trained men. No matter whether the shop is a jobbing or a production shop, good foundrymen will always be in demand.

There is, perhaps, some truth in the theory that it is almost impossible to induce young men to take up foundry work. Why is this true? Some say that young men are no longer willing to

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work at dirty work, others that young men are not as willing to learn as formerly. It has even been suggested that the young women friends of the young men object to them working in foundries. Many other theories have been advanced, some patently false, some ludicrous, while some are at least partly true.

Young men are just as willing to work at dirty work today as they ever were. They are just as willing to work hard and to learn as formerly. We are, however, trying to use antiquated methods on modern men and therein lies the difference. They must be shown what we have to offer to arouse their interest. With foundry work becoming more scientific every year and young men becoming more interested in scientific things, no difficulty should be encountered in bringing young men into the foundry, where, of course, proper methods must be used in handling them. They must be shown that real problems are encountered in the production of castings and that the work is not all physical but that much of it is mental.

Perhaps the greatest obstacle to the securing of new men is the foundryman himself. To him, the foundry has become a commonplace shop and he does not take the pains to show the many interesting phases of foundry work. Students entering the foundries at the universities do not, as a rule, have an interest in the work. As they learn more about it, however, they become genuinely interested. If this interest can be aroused in school foundries where only the fundamentals are touched upon and those only in a brief way, surely as much can be done in the commercial shop.

The working force of a foundry consists of two general classes of men, first those who actually do the work, and second those who supervise and plan the work. The men in the first class need not be highly educated nor do they need to be of the type who have the willingness and capacity to assume responsibilities. In the second class, we need men with some education, who have good judgment and who are capable of assuming responsibilities. Both classes, however, must be well trained in their own special fields.

The men needed both for common and for skilled labor can best be trained in the shops where they are to work, provided that they are trained systematically and intelligently. Most foundries can install a systematic training course under a capable instructor, if they care to do so, at a very small expense. This course when finally in operation can be made not only self-supporting, but can be made to show a profit.

The ground to be covered in such a course of training should be selected from jobs to be made in the foundry. By careful consideration on the part of the instructor, patterns could be chosen

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to have the proper teaching value and at the same time produce needed castings. By advancing the course step by step, so as to hold the interest of the men, progress will be much more rapid than if their interest is allowed to lag.

Great care must be exercised in choosing the instructor for the course. First of all, he must be interested in young men, for any other type of man would not command the respect of the young men receiving instruction. He must also be of good moral character and friendly disposition. He must be a practical foundryman, skilled in the various branches of the foundry industry. He should be able to arouse the enthusiasm of young men, not only in the work, but also should interest them in the available literature. The instructor should be able to give short talks or lectures on foundry work. It has been said that a man with the above qualifications cannot be found, but such men are now actually at work in many of the foundries.

The establishment of such a course would not be easy at first, but when successfully in operation, it would attract many young men to the foundries.

The men needed for supervising and planning the work can probably best be trained in schools provided a suitable course of instruction is offered.

Many colleges and universities teach foundry work as an adjunct to engineering. These courses are too short to provide suitable training for foundrymen for whom more extended courses should be provided.

The foundry course at Purdue University is designed to teach the fundamentals of foundry practice. The work consists of 108 hours, 96 hours being laboratory and 12 hours preparation work. The course is divided into three parts of 36 hours each. The first part, called elementary foundry practice, takes up bench molding. The patterns are selected so that each involves some principle of molding. One mold is made from each pattern by each student. An average of sixteen molds are made by each student besides witnessing a demonstration heat of either brass or aluminum.

The second part or advanced foundry practice consists of floor molding, molding machine practice, dry sand core making, pouring gray iron and cleaning castings.

The third part includes the planning of a small commercial foundry, study of cupola practice, calculation of melting losses and melting ratios and the testing of cast test bars.

All work is done by students, including the making of molds and cores, the pouring of the metals, and the keeping of records. The students take pride in the records and each class tries to improve the record of the others.

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It can be seen that much ground is covered in a short space of time, yet only fundamental principles are taught and these are not drilled into the student as they should be if the course were planned to develop foundrymen.

Numerous attempts have been made to interest the American Foundrymen's Association in the establishment of schools for the training of foundrymen. There is some question as to the advisability of such a procedure, because of the fact that that body is not organized for such a purpose. The National Founder's Association has recently become interested in the subject of foundry training. The latter organization is perhaps in a better position to lend aid to such a plan.

THE FOUNDRY FOREMAN AS A TEACHER

G. F. Buxton

Professor Buxton is in charge of the Industrial Education Field Service of Purdue University. Purdue University is furnishing a service to industry in the holding of conferences on the teaching side of the foundryman's job. These conferences are held at various plants without expense to the company or foremen. The meetings usually last one hour and a half, once a week, the discussions covering not only what will be taught but also the best methods, tricks, and devices for the teaching process.

At least nine men out of ten in our foundries may be classed as operators, and only one as a real molder. This one man may look for future advancement but he must first become an efficient producer. All foundry workers need specific training for the specialized work of their trade. The immediate emphasis must be placed upon the establishment of regular economical motions and fixed habits in foundry practice. The proper judgment of standards and an appreciation of safety demands must be developed early. Care of equipment and an understanding of shop routine should have their place at the proper time. It is important that the instructor know what to give first and that he build up the instruction in a logical order step by step.

In most foundries, the departmental foreman is given the responsibility for breaking in and improving his working force. He knows the needs of his department and is there to watch progress all of the time. He is interested in the man to be trained because he is going to use him, so it is desirable that he give some time to the study of good shop teaching methods.

In some plants it is found feasible to assign a special instructor to the training of green men. This gives a larger opportunity

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for studying the needs of the worker and his interest, ways of developing skill, and the most effective methods of getting tangible results.

A "teaching job" may be done best when planned in detail in advance, listing the things which the worker must know in order to proceed with the operation successfully. There are many good devices to use in teaching, among them may be named the following:

(a) The foreman may "show how" the job is to be done, explaining each step as it is shown, presenting but little new information at a time, and repeating instructions as often as necessary in order to give a clear understanding of the work.

(b) The foreman may ask questions to stimulate the learner's thinking, to check up his understanding of the operation steps, to arouse his interest, and to make him feel at home in the shop.

(c) The foreman may use typed instruction sheets, charts, notes, photographs, mounted materials, or pocket notes as devices to speed up adaptation to the job.

There are no "teaching tricks" which will work well in every case. The foreman should be continually making an effort to improve his ability as a teacher as well as to improve the mechanical and routine means of production.

THE METALLURGY OF CAST IRON

E. J. Lowry

Mr. Lowry is chief metallurgist for the Hickman-Williams Company of Chicago. In that position he has had an unusual opportunity to do much investigational work on gray iron castings.

There is a large amount of information on the metallurgy of cast iron, both physical and chemical, which the foundrymen have attempted to utilize in their practice. The majority of foundrymen, however, do not feel that this information, even though carefully collected, has been properly applied to problems in the foundry industry. The engineer is prone to accept data printed for educational purposes and incorporate it in his specifications. If the castings made according to these specifications do not prove satisfactory, he is liable to become disgusted and substitute malleable iron or steel where gray cast iron should be used. The difficulty encountered in applying the results of research to concrete problems lies in the wide variation in melting and molding processes as well as in the variety of test bars and the methods of testing them.

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The chemical limits specified by different purchasers vary widely as is shown by the following:

	Si—	S	P	Mn	Total C
Automotive castings	1.65—	0.07—	0.12—	0.40—	2.90—
	2.85	0.15	0.55	0.95	3.70
Radiators	1.65—	0.06—	0.45—	0.40—	3.10—
	2.35	0.12	0.68	0.80	3.60
Stove plate	1.90—	0.09—	0.40—	0.40—	3.00—
	2.75	0.12	0.90	0.90	3.60

Each set of specifications is intended to give the best castings for the particular kind of service to which those castings are to be subjected, yet the specifications are so variable as to arouse wonder. It was formerly the custom not only to write chemical specifications, but also to designate the raw materials to be used. This allowed some foundries to monopolize certain work because of the availability of these raw materials. These are being discarded for more consistent practice, and standardization is being sought in the foundry as well as in other industries.

Some type of test bar is generally used in making an investigation and the test data collected is applied to a few castings. If the castings are satisfactory, the results are accepted and published for the benefit of others. Limitations are usually given in these papers, but are often overlooked with the result that when the information is applied to other work, trouble results.

Metallurgy is not incident to the foundry, but is a part of it. The quality of a casting is dependent upon the sum of the effects of the elements in it. The possible combinations of elements in a casting are so numerous that any one individual in a lifetime of work could not determine the properties of all possible combinations. For instance, a high carbon content with a low silicon content will give as strong an iron as a lower carbon and higher silicon. In the latter case, the carbon formations are not as numerous and the continuity of the iron matrix is not broken up as much as in the former. In the former case, the matrix is more broken up, but the strength remains due to the elimination of the silicides which have a weakening effect on the iron and make it more brittle.

Carbon tends to combine with iron to form carbides thereby increasing the strength. In the presence of silicon, however, this combination is prevented and instead a silicide of iron is formed, the carbon being liberated as graphite.

Phosphorus is thought to impart fluidity to gray iron and for that reason to be a benefit. Only within the last few years has phosphorus been considered a detriment in a great many castings. The eutectic composition, which occurs at 6.7% phosphorus in iron containing 2% carbon lowers the solidifying tem-

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perature 536° F. or 80° F. for each 1% of phosphorus present. It seems evident then, that small amounts of phosphorus do not have the great influence sometimes claimed. It is not the actual lowering of the solidifying temperature that causes the fluidity as much as the indirect influence of the phosphorus. This element tends to free the carbon from the iron, forming graphite, thereby producing a composition which retains heat more readily. However, this unstable condition of iron containing phosphorus causes shrinks in the castings.

There is a considerable diversity of opinion as to the effect of manganese in cast iron. Makers of southern iron claim that their iron will make excellent castings, while northern furnacemen are equally insistent that manganese is a cure for trouble. Some claim that inasmuch as manganese helps to produce a high grade steel, a high percentage of manganese should be used in gray iron to produce the best results. As a matter of fact, the effect of manganese is little known. It is known that manganese neutralizes the effect of sulfur in a casting when twice the latter plus 0.15 equals the percentage of the former. An excess of manganese produces a more dense metal. The grain is refined and strength increased. This same effect can be accomplished, however, by altering the percentage of other elements present.

A proper balance of the five major elements in cast iron will always give the strongest and best castings. This balanced composition depends upon the nature of the work produced and the method of producing it. The metallurgist should know from the appearance of the fracture of a casting whether or not the metal is most suitable for the work for which it is to be used. The practical foundry operator should also know what molding methods will produce the best results with the iron used.

When one speaks of strong castings, one usually means either semi-steel or high test cast iron. The former is one kind of metal having several grades. The name, semi-steel, is not, as a rule, accepted by engineers, because of the fact that the term is somewhat misleading. The product does not approach the properties of steel nor is the mixture going into the cupola half steel. In order to remove this uncertainty some method should be found to classify the product now known as semi-steel.

The name "'high-test" indicates that the iron is strong and for that reason is more acceptable to the engineer. High test irons can, however, be made without the addition of steel to the cupola charge, for that reason the name should be qualified in order to show whether or not steel had been used.

Whatever information is available as to the strength of cast iron has come from tests made on test bars. The engineer is often mislead into believing that the strength of the iron as indi-

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cated by these tests is the actual strength of the iron. These test bars often bear little relation to the castings. They are usually cast in a separate mold and are of an entirely different section than the castings they are supposed to represent. There is at the present time no adequate method of determining the strength of a casting. The Fremont-Portevin test approaches the ideal more closely than any other, yet leaves much to be desired. The difference in section between the casting and the test bar causes differences in the cooling rate which is the chief factor governing the strength of the finished product.

These facts have been touched upon in order to show that due to differences in section and design, as well as differences in melting and pouring conditions, results published for the information of the foundrymen will not be the same as the results obtained in other shops.

THE MANUFACTURE OF STEEL CASTINGS

William Woodhall

Mr. Woodhall is chief metallurgist for the National Car Coupler Company at Attica, Indiana. For some years he has been in charge of the plant laboratory and has there studied many of the practical problems of the steel casting industry.

The story of the manufacture of steel from the beginning reads like a romance. As civilization has evolved through the ages, so iron has come into its own today and largely as the basis of steel making. Of all the metals, iron and steel are the most useful to mankind. This is demonstrated every day as ingenuity works them into new forms and adapts them to new purposes. Today steel holds first place and bids fair to do so as long as civilization continues. Our English ancestors were first responsible for the early steel knowledge in our own republic and the steel making industry, by leaps and bounds, has opened up men's minds as to its real possibilities and adaptations to human needs. Steel will find still wider fields and functions; will become a necessary link in more processes of manufacture; will be found in still more combinations with other elements; will be ever increasing in universal use. The number of finished articles into which the metal can be formed are countless. It is found in the application of all trades, arts and professions. Our metal reproduces itself from the time that the mining machines dip into the earth until the product, having fulfilled its mission, is ready to go back again to the furnace to be remelted and refined and brought forth again for a new cycle of service.

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This paper will deal chiefly with the manufacture of steel castings by the acid open hearth steel furnace method. A great many of the steps following will, of course, be adaptable to any process of steel casting manufacture. It is generally recognized that the acid open hearth is, in the most cases, the best process for the manufacture of steel castings. This statement may be open to some challenge, but for both production and quality, acid open hearth is preferable in the tonnage foundry.

The steel casting, when finished, tells us no story of the number of steps required to produce it. First comes its design. It must be able to do the character of work required of it, namely, sustain heavy or light load, under constant or intermittent strain. A few years ago, it was thought that a casting made of steel must have a large cross-section of metal or the molten steel would never fill out the mold. Today, engineers are going to the other extreme—that of designing castings with very thin walls (in a great many cases too thin), so as to cut down the weight of metal and the cost of the casting. This may be all right in some cases, but this tendency to cut down cross-section is creating more expense in the long run, as more replacements become necessary. A happy medium, however, will probably soon be reached, from the standpoint of design as well as of service.

Next, a pattern must be made from the blueprints of the engineer, and from this pattern eventually, step by step, will come the finished product. Right at this point let me state that the proper vision of the finished casting must be had by someone in authority, who can look through all stages of the process and see just where the steps of manufacture will lead him. It is in the pattern shop that the simplification of the molding must take place, for we cannot, as a rule, rely very much upon the coremaker or molder to know the best steps in the manufacture of a casting, so that, as it proceeds through the shop, it will go along smoothly without hesitation at any one place.

The modern pattern-maker must forget a lot of old methods and make his pattern in such a way that the molder will have the least amount of work to do. Let us take, for example, a pattern coming into the shop with large portions down in the drag that ordinarily would have to be made in the cope and hang down into the drag. Instead, the modern pattern-maker should look ahead and make core boxes for these protruding pieces, so that the molder will be able to put in a couple of cores instead of having a heavy cope to contend with.

Then, again, the pattern-maker must be able to change old patterns or older methods to methods adaptable to machine molding, so that production will be hastened. Another saving from the pattern shop is in the taking apart of the split patterns,

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one-half to be used in the drag and the cope half to be put in a core box and rammed up from dry sand and used as a cover core, thus doing away with the cope entirely.

Another question confronts the pattern-maker; will the finished casting be satisfactory if it contains normal shrink holes, or will it have to be made with expensive heads and risers to take care of the shrink and the gas?

Repairing is a very important item in the pattern shop, for in a steel foundry, ramming and constant use of the pattern soon puts it out of commission and it must be gone over very thoroughly. If the job will warrant the expense, aluminum patterns are more satisfactory for production work.

After the pattern is completed, together with core boxes and core prints, it goes to the foundry and core rooms. Here we see great changes in shop methods. Wherever a job can be made on a machine in order to get out a larger number of molds, it is by all means done, for we must keep up production. More than ever before, is it necessary to use machine molding, for skilled mechanics in the molding trade are few and far between, and we see very few of the old type of skilled molders who learned their trade by four years of apprenticeship. Probably the Jolt machine is as good an illustration of machine methods as we have for keeping up production. Here one good molder can direct the operations of several machines and yet get good castings. In this way it is possible to increase production by means of unskilled labor.

Let me mention again the molding method in vogue today without use of a cope, a cover core taking care of cope work and then cutting down the time considerably. There are, however, some jobs that cannot be made by the cover core method. More and more, green sand work is supplanting dry sand molding. As a rule, the best castings can be produced from green sand drag molds and a cover core made of dry sand. Most of the dirty castings are produced by washes from the top of the mold in green sand cope work. The dry sand cope eliminates this trouble.

Dry sand molds are generally made when the sections will be large, and when the casting must be machined. Dry sand molds should do away with swelled castings and give a fairly uniform casting throughout. Clean shaving joints about one inch back following the mold contour and approximately 1/16 inch to ⅛ inch should be made. The thickness of this shaving depends, of course, upon the weight of the casting.

When we have thin sections of metal to cast, the green sand has a natural give when the molten metal pours into the mold that is beneficial. Fewer cracks and better castings are the

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result. Green sand molding is the cheaper method. It eliminates drying-ovens, extra crane service, and a dry-floor man to put up molds after drying. Thus green sand increases production. Molds must be made in heavy steel flasks for dry sand work and this is a considerable item of expense, for all lifting must be done by crane service. In green molds, we can use wooden flasks which can be turned over by hand and thus save expensive crane handling. You say that wooden flasks are expensive, but the increase in production more than offsets the cost of the flasks. Wherever green sand can be used, it is the more economical in the end. A great many castings must be made, however, by the dry sand process.

Careful sand mixing is necessary in any foundry. There is no hard and fast rule for this, conditions in each foundry probably differing somewhat from all others. Sand and fire-clay vary and thus the mixtures have to be made up and tested by actual use and someone in authority must be designated to watch this one item alone. Years of experience with different sand mixtures enable a mixer to get excellent results, but even then a variable factor, such as extra-poor or old burnt sand, will change the entire outcome.

In the acid open hearth method, the sulfur and phosphorus are not eliminated as in the basic process, for this reason the raw materials must be carefully selected. Specifications for steel castings usually allow less than 0.05% phosphorus and sulfur. In order to meet this requirement, the following analysis of raw materials has been found to be satisfactory:

	Acid Pig Iron	Acid Scrap
Silicon, per cent	1.5 -2.0	0.20 -0.30
Sulfur "	0.03-0.035	0.035-0.04
Phosphorus "	0.03-0.035	0.035-0.04
Manganese "	1 -2.0	0.65 -0.75
Carbon "	3.5 -4.0	0.15 -0.25

The specifications to which the metallurgist must work for finished castings depends upon the service to which the castings will be subjected. Most work in a tonnage foundry is of the railroad class of castings. A summary of these specifications follows:

1. **Scope.** These specifications cover all steel castings for passenger and freight car equipment, including couplers, truck bolsters, truck side frames, yokes and miscellaneous castings.

2. **Process.** The steel may be made by open hearth, crucible or electric process.

3. **Heat Treatment.** Castings shall be allowed to become cold. They shall then be uniformly re-heated to the proper temper-

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ature to refine the grain and allowed to cool uniformly and slowly.

4. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Carbon	0.20-0.37	per	cent	
Manganese	not over 0.75	"	"	
Phosphorus	" " 0.05	"	"	
Sulfur	" " 0.05	"	"	

5. **Ladle Analysis.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulfur. The analysis shall be made from drillings taken at least ¼ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform with requirements specified in Section 4.

6. **Tension Tests.** The steel shall conform with the following requirements as to tensile properties:

Tensile strength, lbs. per sq. in.	65,000
Elastic limit	40 to 50% of tensile strength
Elongation in 2 inches, per cent	not under 0.22
Reduction in area, per cent	0.35

7. **Test Specimens and Annealing Lugs.** Specimens for use in testing machine must be made according to sketch submitted. Annealing lugs must be attached to castings so that they can be easily broken off by inspector.

It is very easy to see, then, that the satisfaction given by the finished casting depends on careful control of chemical analysis.

In order to meet specifications, the metal must be uniformly clean. By that I mean the metal must not show segregation due to impurities. It is a well known fact that impurities such as sulphides and slag inclusions cause segregation. Immediately surrounding these inclusions we find a streak of almost pure iron. The iron carbide, in whatever form it may be present, will then collect itself further from the inclusions, thus making a segregated area of one streak of pure iron and then a streak of the harder portion of steel, namely, iron carbide and iron together, called pearlite. These segregated portions of the steel often go under the name of "ghost lines." If we have excessive ghost lines, we have weak metal and it will not be as strong as a more uniform steel. The least number of these ghost lines, then, is most desirable for a good clean steel. Alumina gets into the

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metal a great many times from the ladle linings that are set up with fire clay. This is also a detriment to good steel and causes weakness.

There is only one good way to distinguish dirty steel from clean steel, and that is by aid of the microscope and the science of metallography. More dirty steel results after it passes from the furnace than in the furnace itself, for in the furnace the high temperature allows the slag to gather mostly on top, just like cream rising on milk. Most of the dirt in steel comes from the ladles or from washes from the upper cores or copes in our molds and it is here that we should first look for troubles when dirty steel is being poured.

Just a few words about the furnace. The scope of this paper will not allow many details and I cannot take time to touch on more than the acid open hearth furnace.

Our raw materials, about 20% pig iron, 80% scrap are taken from the yard, loaded in tubs on cars and taken to the furnace floor. Here the charging machine picks up each tub and deposits its contents in the furnace. A charging machine is a necessity in a tonnage foundry, for the more quickly the charge is made, the faster we can get the finished metal out. A heat is made in approximately five hours. Tapping, repairing of furnace lining and refilling take up an hour's time, so that we are able to get out four heats a day. The best of furnace sand is not too good for the bottom and side walls of the furnace, as poor sand results in an extra heavy slag and bad cutting of bottom. A chemical analysis of furnace bottom sand is almost useless as it is the physical properties that are the most important. The sand must have high silica content and must contain just enough bond to fuse properly and "set" in place. High temperature should not cause it to run, for this, together with slag action, causes the lining to "cut."

In a foundry producing only a few grades of steel such as soft and medium steel, carbon from 0.20 to 0.40%, the calculation of the charge is very simple. When the charge is melted, the melt is ored. The manganese and silicon are first oxidized and make up the slag. Then the carbon commences to "boil" out. The consumption of ore should not exceed 6% of the weight of the charge, and in most heats will be below this figure. Pig iron, high in silicon and low in manganese, may frequently cause embarrassment in that the heat melts high in silicon with the result that much time is spent in elimination of the silicon by means of the ore. Confronted with such conditions, we must cut down the proportion of pig iron so that the charge will be low in carbon, yet contain enough silicon, when melted, to protect the carbon from oxidation. The bath will then melt at about the

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carbon content of the charge, and we can run it down with little or no ore. If it melts too low in carbon and is hard to heat because it will not "boil," we can "pig" it to assist operations.

At all times the furnace man watches his roof, walls and ports closely, keeps the flame down to the bath and slacks the temperature by shutting off the air and lowering the stack damper when he sees his brick-work showing signs of melting.

A test of the metal is taken by means of a small test spoon, which is first warmed and coated with slag, then dipped deep into the bath and rapidly withdrawn. A small test mold is filled and any metal remaining is poured slowly from the spoon to judge its temperature. If it pours out clean from the spoon, it is very hot, the more remaining in the spoon the colder and "wilder" the metal. The slag adhering to the spoon is also examined and by its color the progress of the elimination of iron oxide is watched. When the steel is cold and wild it scintillates and "rises" strongly in the test mold. By the fracture of the test piece or by color carbon analysis the melter estimates the carbon of the bath and judges whether or not more ore is needed to eliminate the carbon still further.

The best metal is made by adding small amounts of ore, rapidly at first, and then more slowly. Of course, if the carbon is not "sliding" down fast enough in the melter's opinion, more ore must be added to cause it to do this.

The effect of the ore should be pretty well worn off at least thirty minutes to an hour before tapping and a very good practice is that of getting all the ore into the furnace as soon as possible after melting and having the carbon "slide down" rapidly at first, then less rapidly, and then very slowly. By this practice the iron oxide in the slag, available for oxidizing silicon, manganese and carbon, is practically all exhausted before the heat is tapped and the iron oxide is largely eliminated from the steel and taken up by the slag. As the effect of the ore wears off, the "raise" becomes less in the test mold, the slag grows less black and watery, and the metal pours more cleanly from the test spoon. The temperature of the steel is followed by the indications already described. When the carbon is low enough so that the heat may be tapped, the metal should be so hot that it will all pour out clean from the test spoon. If it does not, the temperature should be increased, holding the carbon up by additions of "pig" or ferro-silicon until the steel will pour reasonably clean. If the ferro-silicon, pig or ferro-manganese, used as re-carbonizers, are added in the furnace, which is the proper place, a last test after they are all melted does not come amiss.

This last test, if the silicon (or both silicon and manganese) has been added, should pour perfectly clean from the spoon and the test should be quiet and flat in the mold.

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Some furnace men add ore till the carbon is racing down and the steel is full of oxides, the tests skulling the spoon and scintillating and rising in the mold; then throw in ferro-silicon and pig iron to check the elimination of carbon, tap the heat as soon as these are melted, add the ferro-manganese in the ladle and pour the steel. They melt the metal hot and keep it hot, but the metal is full of oxides, wild in the molds, and of very poor quality. By heavy additions of manganese and silicon and frequently of aluminum, the steel is quieted enough to make fairly sound castings, but it is not good steel.

When the heat is tapped the furnace men scrape out and close the tap hole, warm up the furnace and shovel sand all around the slag line of the hearth to repair the damage and cutting done by the slag. The furnace is then heated hot enough to set the sand and is then ready for the next heat.

The care of the ladles is a very important item in manufacturing steel, for if the ladle goes wrong anywhere the whole heat suffers. The ladles should always be in charge of an experienced man who has proven his worth. He must be able to make ladle linings that will not crack and spall and must have them heated up to the right temperature before the steel is ready for them. A great deal of responsibility then rests on both head melter and ladle-man. As soon as the ladle and contents swing free from the furnace platform, the skill of ladle-man and his assistant come into play, as they direct the stream of molten metal into the waiting molds.

It looks simple, but the skill of the ladle-man many times spells either success or failure in getting a good, smooth job or a strained or forced casting. During the pouring of each heat, test molds for both chemical and physical tests are made and these are stamped and sent to the laboratories for complete analysis. This analysis consists of chemical examination, physical pull tests, and a microscopic examination. The chemical analysis, of course, is made immediately to determine the percentage of carbon, phosphorus, sulphur, manganese and silicon. The test bars are also made for, and tested in a tensile strength machine to determine the ultimate strength, elongation, elasticity and reduction of area. This is done after the test piece has been annealed with the castings. A microscopic examination is also made after the pull tests and in this way the laboratory has a final check and absolute protection. Today, more than ever before, metallography plays a great role in the steel casting industry. The remarkable growth of this phase of scientific control in the foundry is sufficient and ample evidence of the value of the method. The metallurgist then must be familiar with this new science, for it is one of his greatest helps.

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After the molds have cooled, so that they can be handled easily, they are taken to the knock-out floor, where the castings are shaken out. This floor consists of a great number of grid openings through which the sand goes to large underground hoppers, and these in turn feed several belt conveyors. The sand is then conveyed out of the shop to waiting trucks, which dispose of the burnt cores and sand. Some of the sand is used over again in the new sand mixtures and is taken to the sand mills. The underground conveyor system is a very great time saver and aids production. After the castings are shaken out, some of the risers are knocked off, where the section is sufficiently thin that this may be done. At this point we must have our first inspection of the castings and a good inspector is absolutely necessary. He must be a rapid worker for the progress of the castings should never be halted, as this results in loss, but he must discover as many as possible of the castings that must be scrapped. The inspection is quite necessary at this point to prevent the heavy cost of putting the poor castings through the sand blast and cleaning room, finally to discover that they must be scrapped due to mispour, cracks, shifts, and swells.

From the knock-out floor, the castings are conveyed to the sand blast, where all adhering sand is cleaned off in the quickest and most efficient manner known today, no other system having been found which will do the work as well.

The cleaned castings are next conveyed to the cleaning room proper, where the second inspection takes place and where hitherto undiscovered poor castings are found and scrapped. The fins, risers, gates, and heads are next burned off by oxy-acetylene burning torches. The proper manipulation of these torches is quite an art and requires the best of skilled labor.

The next step in the finishing of the casting is to grind down rough surfaces or protruding portions, so that the castings will be square or will fit the finished gauges. The larger castings are taken to blocks above which hang swinging grinders. Attached to these grinders are two long handles which enable the operator to turn the grinding wheels in any direction and to exert pressure on the surface to be ground. Small castings are ground on ordinary stationary grinders. The best wheels to use are either corundum or carborundum, as these quickly cut off the undesirable portions of the steel. Portions that cannot be reached by grinders are chipped by power chippers. Holes are chipped out by power hammers. The casting now presents a fair appearance and is ready for the refining of its coarse crystalline structure, which is accomplished by means of proper heat treatment in large annealing furnaces.

To get out the greatest production, these furnaces must be so designed as to be continuous, that is, one batch of castings being

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heated while the other batch is cooling. It is the province of the engineering department to design the furnaces, using approved methods of getting the proper combustion chambers for the fuel in hand. If using oil, burners that use the minimum amount of fuel and use vaporization by air are desirable. A great many burners today take more fuel oil than is actually burned. Either the mixing with air or steam is not carried out properly or the burner is poorly designed. It is a good thing to test out several types of burners by means of oil meters and see which gives the most heat for amount of fuel used. Fuel oil used indiscriminately gives increased cost of production, for in a large steel casting foundry many furnaces are necessary.

Another very important thing is to get proper temperatures in the annealing furnace for the kind of steel being annealed. The coarse structure of steel castings is not refined at temperatures slightly above the upper critical range. A much higher temperature is necessary to break this coarse grain. My experience has been that the higher the temperature at which the heat has been poured into the mold, the higher the annealing temperature must be. A simple way to test this is to pour from the test spoon into test ingot a sample from the furnace and note the number of seconds required before freezing of the metal. Similar ingots were made, one from an ingot sixty seconds hot which had to be heated to about 1800° F. to refine the structure, while the other was cast and took only forty seconds to freeze, and annealed properly at 1700° F. When we pour very thin sections of metal, we have to use higher temperatures than for thicker sections. These castings take a much higher annealing temperature. It is the duty of the metallurgist to determine proper temperature at which good refinement of grain is accomplished. Today, more than ever before, it is quite necessary to use a good pyrometric system to measure temperatures within the furnace. The thermocouples are generally placed in the furnace roof. This necessitates getting the difference in temperature between the roof of the furnace and castings themselves. The next thing to determine is the length of time necessary for castings to remain at the proper temperature to get thoroughly heated. Castings one inch through at the thickest section should be held for one hour. After the proper soaking, the casting can be cooled, by either drawing from the furnace or allowing to cool in the furnace. Cooling in the furnace is true annealing but results in a larger grain structure than that caused by cooling in air. Most of the present day work is cooled in quiet air, and this makes for small grain size. This air cooling process is called normalizing.

As we must keep up production without the sacrifice of quality it is quite necessary to have one car of castings ready for the

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oven as soon as the heated castings are ready to draw. This completes a cycle of operations and the castings are then ready for the finishing touches. If the castings have been heat-treated properly, they will not show excessive scale, unless the ovens are leaking large amounts of air. If the flames are kept slightly reducing or even neutral, we get our best looking castings. An oxidizing atmosphere in the ovens always gives thick scaled results which are undesirable.

The annealing operation then consists of:

1. Heating the steel uniformly to the proper temperature.
2. Soaking it at this temperature to assure complete penetration.
3. Cooling it until the color disappears.

This annealing process is of the highest value and importance, and scientific annealing implies expert supervision.

The test bars at this point are taken after cooling to the physical testing department where they are prepared for the tensile strength machine. After testing, a piece is taken from the bar, ground flat, polished and etched by different reagents to bring out the grain structure. It is then examined under high magnification and the results of the annealing operation checked. One familiar with the grain structure can see at a glance just what has taken place. It is a constant check on the human element, and proves conclusively just what the operator of the furnace has done. The physical properties of steel are much more closely related to the minute structure of the material than they are to the ultimate chemical composition. Today, no one questions the value of chemical analysis in metallurgical work, but the metallographic examination when properly interpreted may be of far greater value. For example, the chemical analysis may reveal steel of, say, 0.30 carbon without our being able to form any idea as to its properties. It may be either hard or soft, have great or no ductility, or have a poor or good tensile strength. The microscope, on the other hand, will reveal just exactly what constituents are present and knowing the properties of these constituents, the metallographer can safely predict what the metal will do when put to use.

Some of the castings after coming from the annealing furnaces must be straightened. This is done while hot, so as not to put any permanent strains on the metal.

The castings, after being cooled, are then gauged, and any castings needing further work are finished completely. Some may have small shrink holes that are welded by an electric arc welder. This prevents their being scrapped entirely. Others may have to have a hole reamed a little larger. Very little work,

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however, remains, if all who have had the casting have watched their work carefully. The final inspection is now made and the castings are sent to the waiting railway cars to be sent to their destination. All transportation, other than crane service, is done by means of electric storage battery trucks. These trucks keep things "moving lively" for material in constant motion spells success in the steel foundry.

SEMI-STEEL

G. W. Gilderman

Mr. Gilderman is Superintendent of Foundries of the Dodge Manufacturing Company at Mishawaka, Indiana. He has watched the development of semi-steel from a foundry kink to a definite metal. In this paper he has given many practical helps to foundrymen interested in semi-steel.

Semi-steel is a term that is little understood. The mixtures parading under this title in the past and the manner in which these mixtures have been made have been so varied, that until a few years ago, semi-steel was considered more or less as a joke. There are still a few foundrymen who are under the impression that semi-steel is merely a close-grained iron. As this metal is made today, however, it is well worthy of the name.

Semi-steel is extensively used in internal combustion engine parts. These castings must withstand severe service and so must be strong and close-grained. Whereas the ordinary gray cast iron has a strength of 2300 to 2700 pounds, semi-steel often reaches 3600 pounds before breaking. Bars have been cast that did not break until a load of 4000 pounds was reached, this, however, is not to be expected in everyday practice.

The exact date that semi-steel ceased to be an experiment is not definite. Formerly when a cylinder was to be cast, a few old files were thrown into the ladle and the mixture stirred in order to get a uniform metal. If the casting came out satisfactorily, the files got the credit, if not, everyone stood around and tried to find the answer. Later, steel scrap was added directly to the cupola, first in small amounts, gradually increasing to 40%. The proportion has since been reduced till now 20 to 25% of steel scrap is considered good practice.

Let us take for example a mixture to produce a casting having a thickness of ¾ inches. The analysis should be,—silicon 1.60%, manganese 0.75%, phosphorus 0.40%, and sulfur about 0.09%. In order to obtain this analysis in the casting, the charge should consist of 60% pig iron, 20% steel scrap, and 20% cast scrap. The pig iron should analyze as follows: silicon 2.30%, manganese 1.25%, phosphorus about 0.40%, and sulfur less than

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0.05%. If the manganese content of the pig iron is too low, the deficiency may be made up by adding ferro-manganese to the cupola.

In making up the charge, the first thing to be considered is the size of the steel scrap that is to be used. If the scrap is heavy, such as the ends of T-rails and I-beams or pieces with a corresponding section, it should be charged directly on top of the coke, keeping a space of about eight inches next to the wall for pig iron. If the scrap is small, the pig iron should be charged first, then the scrap scattered over the top of the pig iron. Scrap as small as ⅛ inch thickness may be used in this way.

Semi-steel should be melted hot. The fuel ratio depends of course on the conditions obtaining in each foundry, however, the general practice is not greatly different from gray iron work. An additional 5% of coke is sometimes necessary when using heavy steel scrap. Small charges, 1000 pounds in a 48 inch cupola or 2000 pounds in a 60 inch cupola, will usually give the best results. Mixing ladles are necessary when pouring small castings.

Semi-steel must be handled somewhat faster than gray iron. This fact must be considered when determining the size of gates and risers. When a riser is necessary, it should be about 50% larger than if for the same casting in gray iron. In allowing for shrinkage, one-eighth inch per foot has been found to be satisfactory.

In the preparation of the mold few deviations from ordinary practice are necessary. More new sand should be used in the facing, as much as one-half in some cases. In no case should the proportion of new sand be less than one-third. In preparing the mold for a casting weighing 500 to 2000 pounds, a skin-dried mold is more satisfactory. The facing in this case should be made up of twenty parts sand and one part of pitch compound. For castings weighing more than one ton, a dry sand facing liberally studded with nails is necessary. The dry sand facing is made by mixing one yard of heavy new sand, 12 cubic feet of sharp sand, 140 pounds of flour, and two quarts of molasses.

All dried molds should be given a coat of black-wash before being dried. Compound facings can best be dried by means of a torch while dry sand facings must be dried with charcoal.

In order to get a high casting pressure, either a deep cope or a built-up runner box may be employed. When it is not possible to use a churning rod, the riser should be covered with sea coal as soon as the mold is poured.

Pattern proportion is a very important detail in the manufacture of semi-steel castings. Before attempting to make a new casting, the drawings should be carefully examined in order to locate any heavy sections attached to light sections. If such are

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found, means must be found to feed these portions or chills must be employed to make them solidify as rapidly as the remainder of the casting. This is well illustrated in the case of a blank gear. In this case, we have a heavy section at the junction of the arm and rim next to a comparatively light section of the arm. In a case of this kind, a spongy spot will usually be found at the base of the teeth when cut, unless precautions are taken to prevent such a condition. The usual method of correcting this difficulty is to use a chill made to fit the casting at this intersection and rammed up in the mold. Similar spongy spots are often found in cylinders and pistons.

In making semi-steel castings, a sound clean metal is the principal requirement. Some flux or scavenger is required in the ladle, the ones chiefly used being aluminum, ferro-titanium and ferro-vanadium. Aluminum melts very rapidly and rises to the top, carrying with it most of the gases contained in the molten metal. The aluminum is rapidly oxidized and enters the slag in that form, leaving little or none of that metal in the casting. Ferro-titanium acts in much the same way as aluminum in that it removes gases. Its action is, however, more intense. When a large amount of this alloy is used, some of it will be found in the casting, but if only a small amount is used, the casting will be practically free from titanium. One ounce of 15% ferro-titanium for each hundred pounds of iron gives very satisfactory results. Ferro-vanadium is used extensively in the manufacture of piston rings. Its principal value lies in the fact that it breaks up the large graphite flakes, thereby strengthening the casting. Iron treated with ferro-vanadium will withstand repeated shock better than an iron not so treated. Two ounces of 30% ferro-vanadium is enough to treat one hundred pounds of iron.

The foregoing remarks give a general idea of methods used in actual practice and are not given as rules. They are intended only as a foundation from which to work.

THE ELECTRIC FURNACE

Mr. W. K. Booth, chief engineer of the Booth Electric Furnace Company of Chicago, gave a very interesting discussion of the electric furnace in the foundry. He described the various types of furnaces used and the work done by each. Of particular interest was his description of the rotating electric furnace designed to melt borings. He also melted a demonstration heat of brass in the newly installed experimental furnace in the Purdue foundry.

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NON-FERROUS METALS

E. G. Jarvis

Mr. Jarvis is Vice-President of the Niagara Falls Smelting and Refining Company. His work with this company, specializing in the production of non-ferrous metals, has given him opportunity to study non-ferrous foundry practice from the practical side. In this interesting paper he has outlined the general practice in the non-ferrous industry and has also pointed out many of the pitfalls incident to the management of a foundry.

There are a few details, which might well be brought up, which, while not new or original, may serve to call to mind some of the many common mistakes made in the non-ferrous branch of the foundry industry. We have just started a new year which promises great prosperity and January is a good time to eliminate bad habits.

First, tune up the pulleys in the grinding room and stop the air leakages around the molding machines. If you have a concrete floor in your foundry, have the molder's helper sweep the stall and sprinkle the floor before leaving each evening. A surprising increase in the percentage of good castings will result. Have your molding machine looked over regularly as there is no place where equipment gets so much abuse as in the foundry. Stop the shifts in your castings by having your iron boxes and flasks measured to a template at least once a month. Put stripping plates on your molding machines. This alone will decrease losses due to bad castings and increase sales because of sharper looking castings. Do not crowd your plates with patterns. The proper practice should be to put less patterns on a plate rather than more. Not everything is adapted to machine molding, but there are various ways in which a large percentage of jobbing work can be handled to advantage by the use of aluminum match plates.

The selection of metals is of prime importance in foundry practice. The best sand, highest-paid molders and most elaborate equipment cannot produce sound castings without good metal. Many foundrymen insist on buying scrap metal and making what they call their own mixtures. Composition scrap usually contains some value 85-5-5-5, some bushings and bearings 80-10-10 or 78-15-7, some with, others without phosphorus—a little manganese bronze 60-38, also manganese iron, and aluminum, now and then a trolley wheel, some railway car boxes containing copper, lead, tin, antimony and zinc, and cats, dogs and old rubber boots! Yet the foundryman will tell you he makes his mixture out of 20% copper, 73% composition scrap, and 7% yellow brass. If an analysis were made daily for one

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month the castings would be found to contain 75-88% copper, 2-7% tin, 3-12% lead, and 1-5% zinc. Some would contain phosphorus, other manganese, and some everything including iron. Day after day the machine shop complains about difficult machining and tough metal, yet the foundryman fails to remedy the trouble at the source. In order to make good castings, metals and alloys of known composition must be used. One of the worst habits in non-ferrous foundry practice is the continual doctoring of the mixture.

In using a flux, select one that will gather the impurities and bring them to the top so they can be skimmed off and the flux pass off in the slag, thus leaving no harmful ingredients in the metal.

If possible, have some smelting company make up your alloy according to your formula, as by so doing the time required for melting will be less than by using new metals. Buying ingot alloy metal is the happy medium between using all new metal and scrap. Ingot composition can always be purchased a cent or more per pound below the price of new metals. The chance of error in weighing the various elements is eliminated and the melting point lowered. Moreover, uniformity is established, a condition impossible of attainment when using scrap metals even though the scrap is carefully selected. With silicon bronze, manganese bronze, aluminum bronze and the great number of other mixtures in vogue, the most experienced man in the sorting of scrap metals cannot sort scrap brass today. It is doubtful if any two foundrymen now use exactly the same composition of metal but some day mixtures will probably be standardized.

The best composition for red metal bronze, for valves, fittings, pumps and pressure goods in general is 85% copper, 5% tin, 5% lead, and 5% zinc. This is an ideal mixture for bronze, having a good red color, is easy to melt, cast, and machine. An 80-10-10 alloy with sometimes a little phosphorus for fluidity is the most popular bushing metal for railway work. Addition of the phosphorus helps to keep the lead from "sweating out" though some founders claim that such an addition makes the alloy too brittle for their requirements. For closing the grain of an 80-10-10 or an 85-5-5-5 alloy, cupro-nickel is very satisfactory. One quarter pound of the 50-50 shot should be used for each 100 pounds of the alloy. This improves the mixture decidedly, especially in pressure goods, such as plumber's supplies. The manufacture of 50 copper, 50 lead was a difficult problem for a number of years. Formerly sulphur was used to unite the metals, but this did not stop the sweating out of the lead. With the use of varying percentages of cupro-nickel (50-50) this problem has been solved.

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Manganese bronze has always given foundrymen the shudders, because of the difficulty both of getting good castings and of meeting the high specifications. This alloy cannot be made satisfactorily in ingots. The best copper must be used, electrolytic or lake, not casting copper. The zinc must be Horsehead or Bertha or of similar quality free from lead as lead must be absent in order to obtain a metal of the required 70,000 pounds tensile strength and 32% elongation. The hardener should be made up from virgin aluminum, manganese, copper, tin, and iron. When the pure brass is molten, the hardener should be added, the mixture soaked for a few minutes and poured. Large gates and risers are essential, as this alloy requires a great deal of feeding.

Nickel bronzes appear every day in one form or another, everyone trying them once. Some succeed in making the alloy but the majority finally quit this highly profitable branch of the business. Of prime importance in making nickel alloy castings, is getting the metal sufficiently hot. This, however, can be done in any type of furnace, the metal being poured as soon as it leaves the fire. A little block of wood should be placed on the surface of the metal and allowed to burn during pouring, or if it becomes necessary, because of sluggishness, to raise the temperature, a little zinc may be added before pouring. Small molds must be skin dried while large molds should be oven dried. Large gates and risers like those used for manganese bronze are necessary. The best results are obtained with Lumberton sand with a small amount of Albany, or sand of like fineness, to give lots of vent to the mold. With these suggestions in mind and a little common sense in gating and placing risers, no difficulty should be encountered in casting this metal.

Common yellow brass (64-2-34) is a good alloy for some castings, but foundrymen often add aluminum to increase fluidity instead of increasing the size of gates and runners. This is a mistake as nothing has injured any branch of the business as much as aluminum in yellow brass. If a check is kept on the loss in melting gates containing a little aluminum, a 10% melting loss will almost always be found. Smelters who buy borings always pay one cent more per pound for yellow borings free from aluminum while some smelters refuse to accept borings containing aluminum.

Aluminum alloys of one sort or another have been developed to suit almost every requirement. Ninety per cent of the aluminum used is in the form of the number 12 alloy (92% aluminum —8% copper). This alloy can be purchased in the ingot form or can be made in the foundry from virgin aluminum by the addition of a hardener. This hardener is usually a 50-50 copper-aluminum

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alloy which melts readily in molten aluminum. It can be purchased, in most cases, more cheaply than the small foundry can make it. If it is desired to make it at the foundry, however, the usual practice is to melt the copper and add the aluminum. Some founders prefer to melt the aluminum and add fine copper to the melt, but this procedure does not give as satisfactory results as the first method. Zinc chloride is the usual flux for aluminum, a teaspoonful stirred into the molten metal will gather all the impurities to the top of the pot and leave the aluminum in excellent condition.

The use of refined silicon in aluminum alloy will improve the physical properties. The addition of 2% of refined silicon to a number 12 alloy, making a metal such as 90% aluminum, 8% copper, 2% silicon, will have physical properties superior to the regular number 12, but its principal advantage lies in its casting properties. It is practically free from the viscosity which characterizes the number 12 and is, at the same time, free from hot shortness. Crystalline shrinkage is practically eliminated with the result that castings, regardless of shape, show a fine dense crystalline structure. For a combination of high tensile strength and elongation a somewhat higher silicon content is necessary. Such an alloy should consist of aluminum 90-92%, silicon 6%, and copper 2-3%. There are also a number of other alloys which have been successfully used, and which have highly desirable properties. For instance, an alloy of 5% silicon, 95% aluminum is resistant to corrosion by salt water and weak acid and alkali solutions. The iron content of all these alloys should be kept below 1¼% as iron greatly increases the brittleness.

The place of the technical man in the foundry industry should not be overlooked. Every industry into which either chemistry or metallurgy has entered, has been greatly benefited. When the technical men are taken into the business, even though it takes a year or sometimes two, to teach them the practical side of the industry, an asset has been added that money cannot buy.

MOTION PICTURE FILM

Mr. George Furman, Sales Manager of the Beardsley and Piper Company of Chicago, gave an interesting description of the Beardsley-Piper sand slinger. A motion picture showing the work done by this machine was also exhibited.

Everyone familiar with foundry work has seen molders throwing handfuls of sand into deep partings or pockets of a difficult pattern. The sand slinger is a machine designed to throw from

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750 to 1800 handfuls of sand a minute. This eliminates all hand ramming and has the advantage over other types of machines in that it can be adapted to any size or type of pattern.

The same machine also conditions the sand while filling the molds. The sand is lifted from the floor, mixed, riddled and deposited in a hopper, ready to be thrown into the molds.

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BULLETIN No. 5. Proceedings of Tenth Annual Road School, by B. H. Petty, 1924.

BULLETIN No. 6. Proceedings of Second Annual Conference of Indiana Foundrymen, by J. P. Walsted, 1924.

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STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

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Thawing Frozen Water Pipes with Electric Current

by
D. D. EWING
and
C. F. BOWMAN

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BY
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and
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Assistant in Electrical Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
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THAWING FROZEN WATER PIPES WITH ELECTRIC CURRENT

I. INTRODUCTION

Purpose of Bulletin.—The purpose of this bulletin is to present a summary of present practices in the art of thawing frozen water pipes with electric currents. Lists of the equipment required for some of the arrangements that have proven successful are given and data on the electrical characteristics of certain small sizes of commercial steel pipe are also presented.

The material presented in this bulletin has been collected from many sources, tests made at Purdue University and compilations from technical magazines and the publications of technical societies.

Where Pipes Freeze.—The pipes most often frozen are those between the street mains and the water consumer's indoor piping. When exposed, such pipes may be thawed readily with a blowtorch. Usually, however, blowtorch thawing involves digging away frozen earth; also there is no assurance as to the exact location of the frozen spot, and there is danger from freezing again because of poorly tamped soil about the pipe. Most cases of frozen service pipes come a day or so after the cold spell has passed. During the actual cold spell the water is usually allowed to flow, thus protecting the pipes against freezing. After the peak of the cold wave has passed above ground and before the ground has warmed—perhaps even before the minimum temperature has been reached by the soil about the pipe—the water is left turned off and freezing occurs.

II. ELECTRICAL METHODS OF THAWING

Three general methods are used for thawing pipes by electricity:

(1) **Using a metallic heating element,** in or on the frozen part of the pipe, maintaining contact between the electric heater and the ice plug until the ice is melted. This method is, in general, similar in possibilities to the blowtorch method.

(2) **Inserting an energized wire in the pipe,** the return being through the pipe. The pipe filled with water becomes a water-rheostat, and the heated water melts the ice-plug.

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(3) **Heating by the resistance losses** of large currents flowing through the pipe itself. This is the most common method where the demand is great enough to justify the use of considerable equipment.

The Water Rheostat Method.—This system is shown diagrammatically in Fig. 1, page 4. It possesses the advantages of minimum equipment and one-man operation, but cannot be used with any satisfaction for crooked pipes. The insulation rings, which are left on as shown, and the rubber tip prevent grounding to the pipe. The resistance losses in the water produce the heat that melts away the end of the ice-plug.

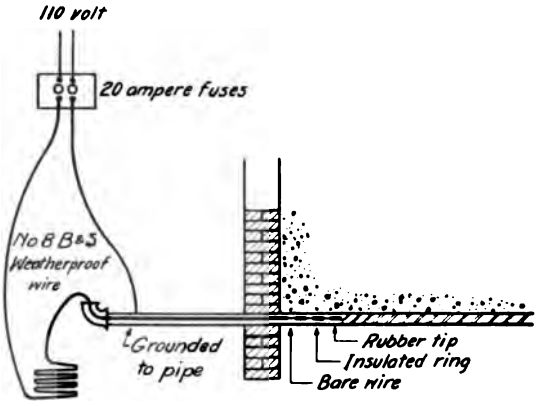


Fig. 1. Pipe Thawing Without Transformers.

This method will thaw from 3 feet to 4 feet of ice per hour, and the current required is about 20 amperes. All of the heat for thawing comes from the electrical energy expended which makes it more wasteful of electrical energy than the third method; but where a comparatively few services are to be thawed it saves the use of the comparatively large amount of equipment required by the resistance loss method.

Thawing by Heating the Pipes With Electric Current

The range of values obtained under different conditions is too wide to allow accurate figures to be given for time, voltage and current required. This is to be expected since soils differ in conductivity and since usually only an unknown small fraction of the total length of pipe is frozen. The upper limit of practicable current, upon which the heating depends, is determined

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in part by the amount of equipment to be used and moved. Another factor is the increase of stray currents, and hence lost energy as the current density increases in the pipe. On the other hand with small currents the time required for thawing becomes excessive, varying inversely as the square of current. Since labor costs, usually for two men, and the use of electrical and transportation equipment play a large part in the expense of thawing service, time becomes a more important element than current cost and must be kept at a minimum.

Currents Required for Thawing.—The magnitude of the currents required depend upon the size of the pipe, and the condition of the surrounding material: whether a good or poor conductor of electricity, and its heat absorption powers. For pipes of from ¾ inch to 2 inches in diameter in ordinary frozen soil, current values of from 50 to 500 amperes have been found to be most satisfactory. This will melt the layer of ice next to the pipe sufficiently to start the water flowing, in from five minutes to an hour. The flowing water will melt the remainder, saving both time and electrical energy as compared with what would be required to melt the entire plug of ice. The saving in time resulting from the use of high current densities is clearly brought out in the curves of Figure 2, page 5. The temperature changes

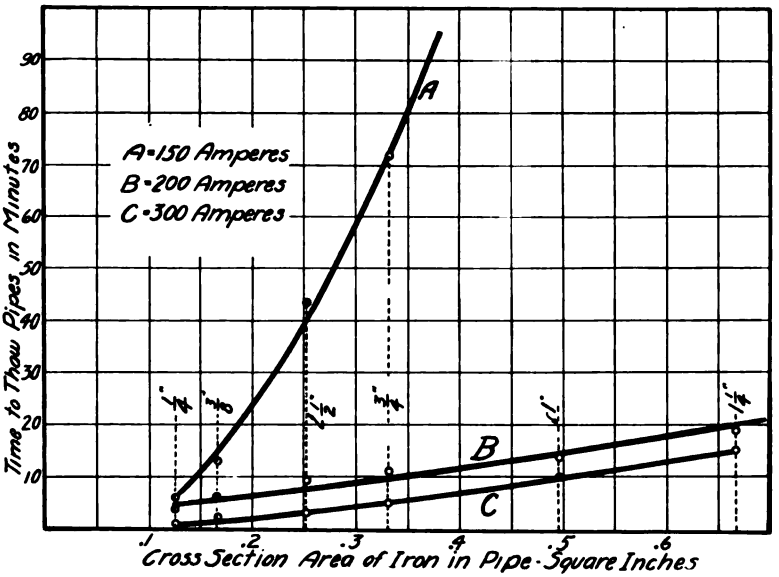


Fig. 2. Curves Showing the Relation Between Current and Thawing Time.

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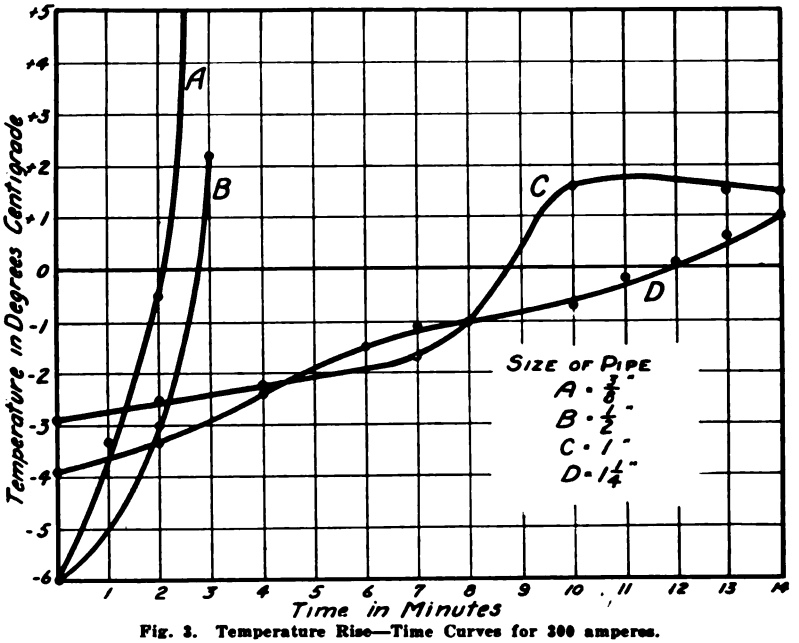


Fig. 3. Temperature Rise—Time Curves for 300 amperes.

of the iron pipe wall itself with constant current are shown in the curves of Figure 3, page 6, for different sizes of pipes.

These curves were plotted from data taken from tests made at Purdue University by C. A. Brown and F. C. Roth in which pipes

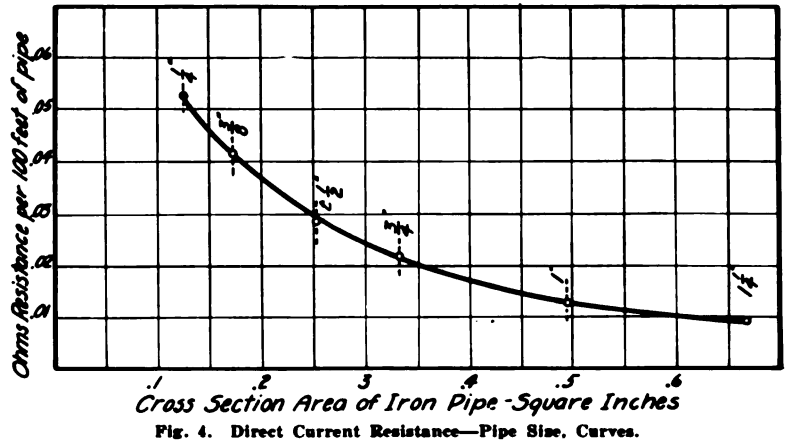


Fig. 4. Direct Current Resistance—Pipe Size. Curves.

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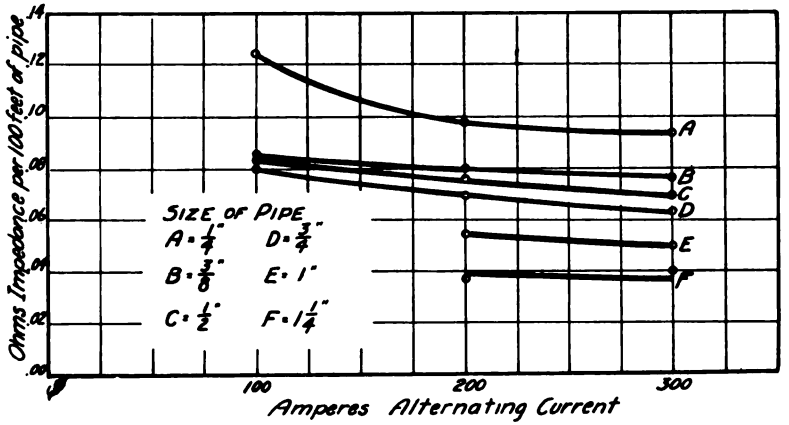


Fig. 5. Impedance—Current Curves for 60 cycles.

in open air were thawed. This method of testing eliminated undeterminable stray currents and variable soil characteristics.

Voltages Required.—The voltages required depend upon the length of pipe, its size, and the amount of current to be sent through it. Since there is a large range of currents allowable, the voltage need not be closely adjustable. The electrical characteristics for frozen pipes of four different sizes, in open air, are indicated by the curves of Figures 4 to 6 inclusive. Values of apparent resistance (impedance) from these curves are given in

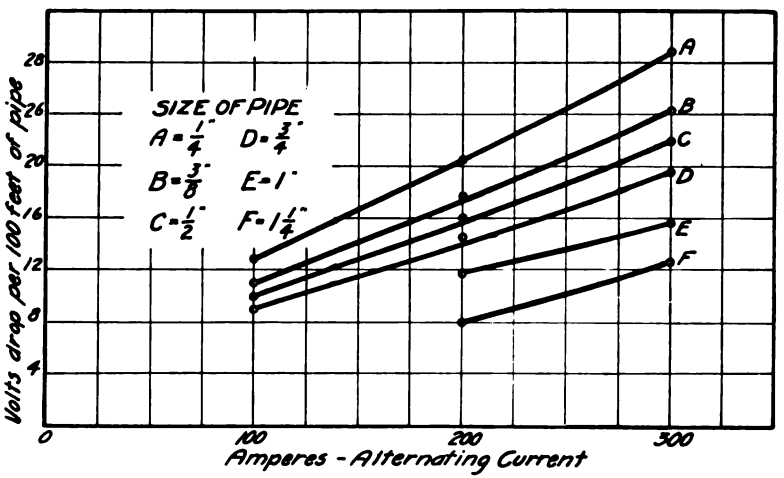


Fig. 6. Alternating Voltage Drop per 100 feet of Pipe.

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Table I. The voltages required for direct current thawing can be calculated by multiplying the resistance given in Figure 4 by the thawing current and the length of pipe in hundreds of feet.

Some installations are arranged to give a close control of voltage but this is not a fundamental necessity. Such control is of value where sufficient use is to be made of the equipment to warrant the extra apparatus necessary to obtain higher electrical efficiencies and greater flexibility.

Alternating Current Equipments

A scheme for an alternating current equipment is shown diagrammatically in Figure 7, page 8. A bank of transformers is connected to the power lines in such a way as to give some control of voltage for ranges of 10 to 110 volts. Spare distribution transformers using series-parallel switches are commonly used, connected to the 2200 volt lines. A Wright demand meter has been used to protect the transformers from excessive overloads,

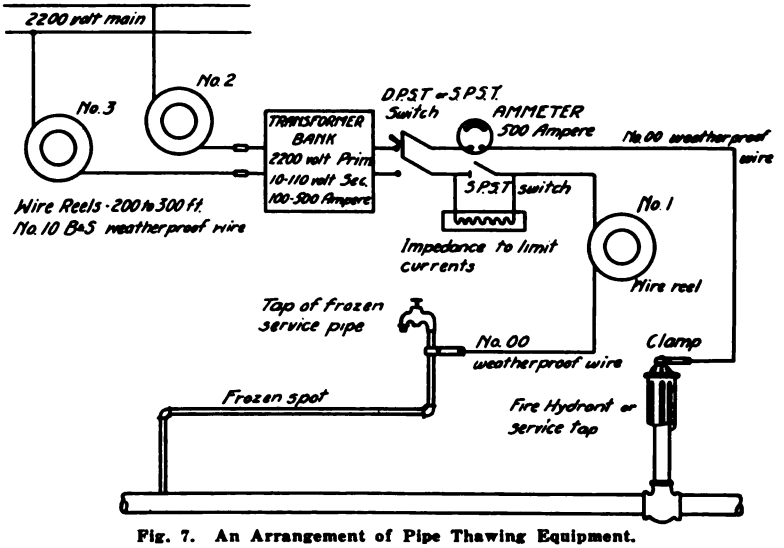


Fig. 7. An Arrangement of Pipe Thawing Equipment.

in place of the ammeter. Unless there is considerable flexibility of control of voltage in the transformers, the impedance should be included to limit currents for short pipes.

The entire outfit, including transformers, switches, and reels is usually semi-permanently mounted on a sled, wagon, or truck.

The impedance may be either a resistance or a reactance. A

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water-barrel rheostat, using 10 pounds of salt to the barrel of water, gives good results. Interchangeable low-voltage leads of different sizes may be used. Current densities in the leads may be somewhat greater than ordinarily allowed, due to the cold air surrounding the wires. For a reactance, a coil of about twenty turns around an old 15 k.v.a. transformer core, or any laminated iron core about 6 inches square is satisfactory. Another scheme is to use an iron core on the low-tension wire reel. In this case the reactance is automatically lowered as the wire is unreeled for longer pipes where the reactance is undesirable.

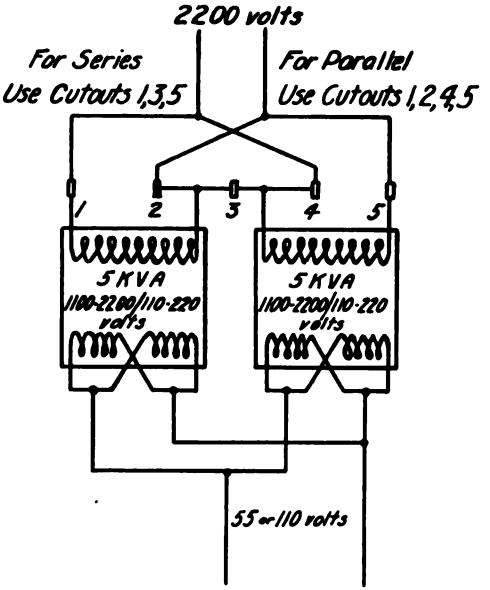


Fig. 8. A Simple Transformer Connection.

Transformer Arrangement.—The transformers can be arranged in a large number of ways. To avoid heavily overloading the regular distribution transformers which would probably occur, power should be taken from the 2200 volt mains in place of the 220 volt lines wherever possible. However, since they are operating only for short lengths of time, and in cold weather, both the special transformers and the distribution transformers may safely be operated at twice rated current or even more.

A simple transformer arrangement is shown in Figure 8, in which two 5 k.v.a. distribution transformers, connected for 2200

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volts to 110 volts transformation, are connected through a series-parallel switching arrangement of fused cut-outs to the 2200 volt mains. When the primaries are in series, the parallelled secondaries give 55 volts; with the primaries in parallel, the secondaries give 110 volts. In either case rated current is 90 amperes, but for duty *outdoors in freezing temperatures* up to 200 amperes may be drawn safely for an hour. This value is ample for ¾-inch and 1-inch pipes, and the 110 volts will be sufficient for any ordinary service connection of these sizes. This arrangement should be operated ordinarily with the series impedance in the low-voltage side to limit the current, and an ammeter should be used as a safety measure.

If two 10 k.v.a. transformers, or larger, are used in place of the two 5 k.v.a. specified, the impedance is not necessary, although it adds to the facility of control; the currents then being within the capacity of the transformers.

An extremely flexible arrangement is one shown in Figure 9. While it is carefully designed, and gives high electrical efficiencies and flexibility of control, it is not used to any great extent as it requires considerable equipment. With the double pole double throw switch thrown to the "series" position the low-voltage range is from 11 to 44 volts in steps of 5½ volts; thrown to "multiple" the range is from 22 to 88 volts in steps of 11 volts. The short time current capacity in either case is 500 amperes. This type of set is especially applicable for use on mains of fairly large size.

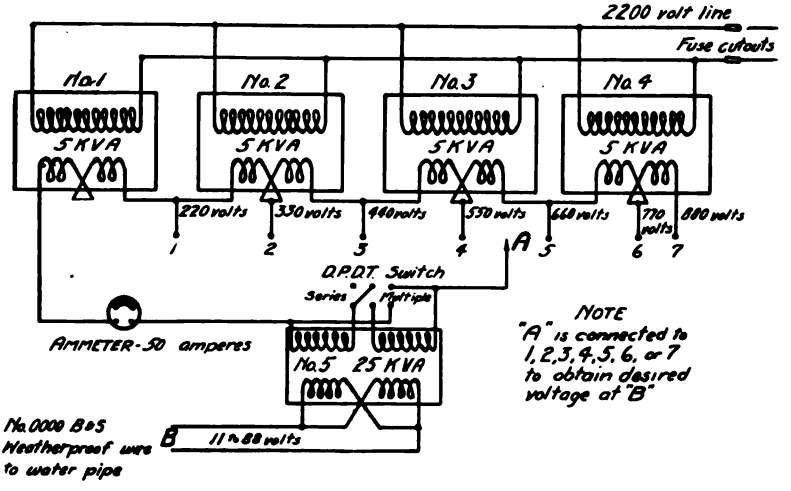


Fig. 9. A Flexible Arrangement of Transformers.

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Operation from 220 volt lines is often desirable. This is especially true where the supply of spare transformers is limited, and more labor can economically be expended to conserve equipment. Sometimes, also, the 2200 volt mains may not be readily available.

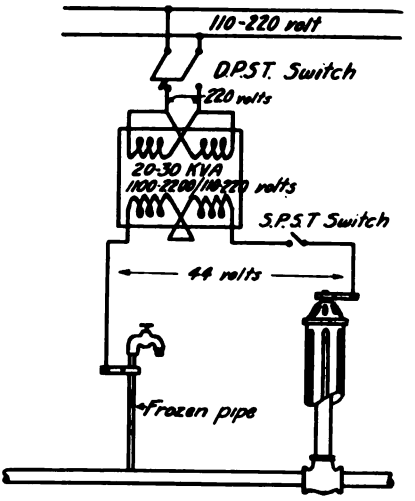


Fig. 10. An Arrangement for 220-volt Supply.

Overloading of the regular distribution transformers is usually unavoidable, and care must be taken to keep the overload within reason by using lower currents and allowing more time.

One connection for this service is shown in Figure 10. In another the primary windings are connected in series and the secondaries in parallel. The connection to be used depends on the size and length of the pipe, and the amount the distribution transformers may be overloaded.

Special Thawing Equipments

A series instrument transformer rated at 80 amperes with a 16 to 1 ratio has been successfully used. The low-current side was connected in series with a bank of eight 80-watt lamps and fed from 110-volt mains. This made nearly 100 amperes available at the pipe, which was connected to the high-current side. With this arrangement a ¾-inch pipe in a power-house was thawed in eight minutes, using 0.042 kw. hr.

Special transformers are available on the market and their greater convenience and economy justify their use where the

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demand for thawing service is sufficient to warrant the investment in special equipment. Some of the small commercial designs operate from a house-plug, indoors.

Direct Current Thawing Equipment

Thawing by direct currents is feasible and has been done successfully. A gas engine-driven generator of 10 to 20 kw. capacity, mounted on a sled or truck and operating at 5 to 25 volts may be used; or the generator may be mounted on a tractor and belt driven from the pulley. Complications enter where a 115-125-volt machine is used, since, due to the shape of the magnetization curve, it may prove necessary to separately excite the generator. Lower than rated speeds may be used, but this lowers the overload capacity of the machine which is lower than in transformers.

Two unusual cases of attempts to thaw pipes electrically have been given publicity. In one case a six-inch main submerged in water of 30° F. and moving 5 to 7 miles per hour was successfully thawed; but it required 600 kw. transformer capacity for three days to do the job. In another case, where a 4-inch main was submerged in tidewater marshes the attempt was abandoned after currents of from 300 to 3000 amperes gave no results after several days.

III. GENERAL RESULTS

Charges and Energy Consumption in Thawing Service.—Charges and energy consumption are matters dependent upon local conditions. The usual job requires 2 to 15 kw. hr. of energy; and a single outfit can thaw up to twenty pipes per day. Tables II and III, page 14, show some values obtained from various sources.

In some cases, notably where both the water and light plants are municipally owned, the thawing is done free as part of the service. In other cases charges are made ranging from $5 per job for ¾-inch pipe to $15 for larger sized pipe. Another plan combines an energy charge with a time charge for labor and equipment, for the larger sizes of pipe; a flat rate being charged for jobs involving smaller pipes. The costs of this service for a number of cities of United States and Canada as abstracted from various sources, chiefly from the Electrical World, are tabulated in Table IV, page 15.

Precautions and Dangers.—These are chiefly as follows:

(1) Stray return currents create a fire risk which is minimized when the house pipes can be disconnected from the frozen

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portion of the service pipe. This disconnection is required in some cities.

(2) Currents must be limited to not much over twice the rating of all apparatus involved, outdoors. This is done by voltage control, or by impedance in the low-voltage circuit.

(3) Properly sized leads should be used, with good insulation, and provided with secure clamps at the terminals.

SUMMARY

The following is a brief summary on the problem of pipe thawing:

(1) For exposed pipes the blowtorch is most convenient.

(2) Where only a few straight services are to be thawed, the thawing is most economically done by inserting a live wire in the frozen pipe and thawing by the water-rheostat method.

(3) Where crooked service pipes are to be thawed, spare distribution transformers may be used in different ways, from either the 220-volt or 2200-volt lines, preferably the latter.

(4) Where there is an extensive demand for thawing service specially designed thawing transformers or home-made equipments with some flexibility in voltage and current control are desirable, as they save both time and expense and minimize the danger hazards to employees.

TABLE I.—Apparent Resistance of Commercial Steel Pipe in Ohms per 100 feet of Pipe on Direct Current and 60 Cycles Alternating Current

Size of Pipe (inches)	Direct Current Resistance	Apparent Resistance to Alternating Current Ohms Impedance		
	Ohms	100 amps.	200 amps.	300 amps.
¼	.052	.131	.103	.097
⅜	.041	.094	.088	.081
½	.028	.092	.080	.072
¾	.022	.088	.073	.066
1	.013	---	.058	.052
1¼	.009	---	.041	.042

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TABLE II.—Sample Data from Thawing Iron Pipes

Size of Pipe Inches Nominal Diameter	Length of Pipe in Feet	Amperes Used	Voltage Required	Time Required in Minutes	Kw-Hrs.
½	60	140	130	20	6.1
½	100	110	120	40	6.6
½	120	120	130	15	3.9
½	125	120	120	30	7.2
½	125	125	100	10	2.1
¾	16	20	---	270	1.75
¾	40	300	50	8	2.0
¾	60	350	110	20	11.8
¾	70	300	110	30	16.5
¾	100	150	55	72	16.5
¾	100	135	55	10	1.24
¾	250	400	50	20	3.3
1	100	150	60	20	--
1	100	150	60	25	--
1	250	500	50	20	--
1	250	480	50	15	--
1	500	200	70	5-60	--
1	700	175	55	300	--
1¼	75	175	115	30	10.1
2	30	60	130	30	3.9
½	50				
2	100	150	130	30	9.8
2	30	110	---	---	59.4
4	1300	260	55	180	42.9
6	one block	---	100	60	75.0
6	700	---	---	150	--
10	800	400	70	120	56.0

TABLE III.—Summaries from a Large Number of Thawing Jobs.

Size of Pipe	Number of Services	Average Length in Feet	Average Current in Amperes	Average Time in Minutes
½C	8	33.7	250	19.6
⅝C	180	36.1	323	8.1
¾C	55	18.2	350	8.3
1 C	75	40.4	340	14.5
1¼C	35	40.8	372	9.5
1½C	12	42.9	360	20.8
2 C	3	52.3	416	13.0
⅝L	2	32.5	287	7.0
¾L	53	42.0	341	9.4
1 L	20	57.5	369	29.7
1¼L	19	61.0	403	26.7
1½L	8	39.3	393	13.7
2 L	2	45.0	450	40.0
Misc. L	125	---	---	30.0

Note.—L, Lead Pipe.
C, Iron Pipe.

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TABLE IV.—Charges for Thawing, 1918

	City	Cost per Job
1.	New Rochelle, N. Y.	$15.00
2.	Madison, Wis.	10.00
3.	Niagara Falls, Ont.	10.00
4.	Patterson, N. J.	8.20
5.	Green Bay, Wis.	7.70
6.	Trenton, N. J.	7.50
7.	St. Louis, Mo.	6.58
8.	Minneapolis, Minn.	5.00
9.	Rutland, Vt.	4.11*
10.	Lawrence, Kansas	3.25
11.	Gary, Indiana	3.00
12.		2.54
13.	Petersboro, Ont.	2.50
14.	Kitchener, Ont.	2.00
15.	New York City, N. Y.	---**

* Average from 866 services.
** Charge is $1.00 per 100 feet, minimum $10.00.

IV. APPENDIX

In this appendix are given the bills of material for some of the thawing sets previously described.

A. Material for the thawing set described on page 4:

1 fuse block.
2 fuse plugs 20 amperes 125 volt.
100 foot wire, weatherproof No. 8 B. & S.
1 insulator tip to fit end of wire.

B. Material needed for the thawing set described on page 8:

2 transformers, 5 k.v.a. 1100-2200/110-220 volts.
5 cutouts, 2200 volts, fused for 7½ amperes.
1 ammeter 500 amperes (optional).
1 reactance (or resistance) optional excepting on short pipes of 30 feet or less.
250 feet wire, weatherproof No. 00 B. & S.
(Secondary leads, 75 feet and 175 feet).
100 feet wire, weatherproof No. 10 B. & S.
(Primary leads, 50 feet and 50 feet).
1 switch 250 volt, 400 ampere, SPST or DPST.
2 wire clamps.
3 wire reels (optional).

C. Material needed for the thawing set described on page 11:

1 ammeter 200 amperes.
1 DPST switch 250 volt 400 ampere.

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200 feet weatherproof No. 1 B. & S. wire.
150 feet weatherproof No. 00 B. & S. wire.
2 clamps.
1 transformer 20 or 30 k.v.a. 1100-2200/110-220 volts.

PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE

BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright, 1922.

CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923 (out of print).

BULLETIN No. 2. House Construction that Reduces Heating Costs, by James D. Hoffman, 1923.

BULLETIN No. 3. Pictorial Description of Engineering Activities, Purdue University, 1923.

BULLETIN No. 4. Electric House Pumping Systems, by G. C. Blalock and D. D. Ewing, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

BULLETIN No. 5. Proceedings of the Tenth Annual Road School, by Ben H. Petty, 1924.

BULLETIN No. 6. Indiana Foundrymen's Conference, by J. P. Walsted, 1924.

BULLETIN No. 7. Thawing Water Pipes with Electric Current. by D. D. Ewing and C. F. Bowman, 1924.

The following material has been issued in mimeograph form:

FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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BULLETIN OF
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VOL. VIII SEPTEMBER, 1924 NO. 11

Connection Checks for Polyphase Watthour Meters

BY

D. T. CANFIELD

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ENGINEERING EXTENSION SERVICE
LAFAYETTE, INDIANA

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BULLETIN NO. 8
ENGINEERING EXTENSION SERVICE

Connection Check for Polyphase Watthour Meters

BY
D. T. CANFIELD
Instructor in Electrical Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
SEPTEMBER, 1924

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CONNECTION CHECKS FOR POLYPHASE WATTHOUR METERS.

I. INTRODUCTION

It is the purpose of this Bulletin to provide an operating manual on the subject of checking the connections of polyphase watthour meters. In this manual all theory as to why the checks operate has been purposely omitted.

The assembling of the material, which this Bulletin contains, in the form of an operating manual was deemed worth while because of the number of polyphase meters actually installed that have been found to be improperly connected. On any large public utility property improperly connected meters are constantly being reported, and it is by no means unreasonable to conclude that there are a great many such meters now in operation in this country.

At the outset it will be well to emphasize the fact that no check subsequently applied is as valuable as correctness of connection in the original installation. At the time of the original installation the lines are usually dead and if all instrument transformers are first carefully checked and thoroughly marked, and a standard method of connecting in the meter is adhered to, the likelihood of making a mistake will be small. Furthermore, many of the checks to be described later, which could be applied at an original installation with comparative ease, are often extremely difficult to apply at some subsequent time. Standardized methods of checking and marking all instrument transformers and meters is to be highly recommended.

The checks that follow are divided into four parts:

1. Special apparatus needed, if any.
2. The mechanical or physical operations in the order of their performance.
3. Simple and conclusive rules for interpreting the results of the operations in (2).
4. Advantages and disadvantages of the check.

Since some of the checks depend upon the number of leads brought to the meter, it is necessary to classify meters according to their connections. The classification adopted here is given in Fig. 1. Thus, a Class A meter refers to one used without instrument transformers where all leads are independently connected to the lines.

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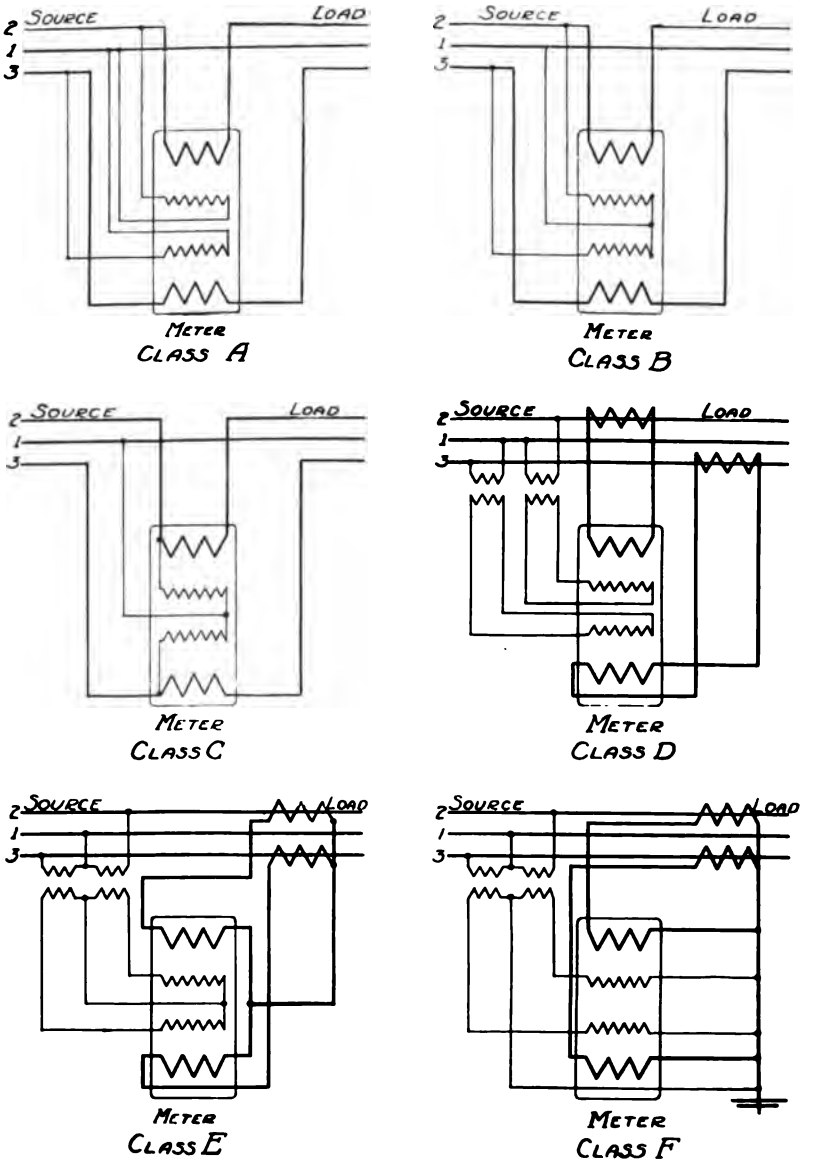


Fig. 1.—Classification of Meter Connections.

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CHECK NO. 1

OPENING THE LINES

Special Apparatus: None.

Procedure:

Step 1. See that the meter is running in the right direction with both elements connected.

Step 2. Open that main line wire which contains one of the current elements of the meter or current transformer at a point on the line side ahead of all taps to the meter and also on the load side at a point behind all taps to the meter, A 1 and A 2, Fig. 2.

Step 3. Note direction of rotation of disc.

Step 4. Close the line at the points opened in Step 2.

Step 5. Open the other line wire which furnishes current to the meter at two points, as in Step 2, B 1 and B 2, Fig. 2.

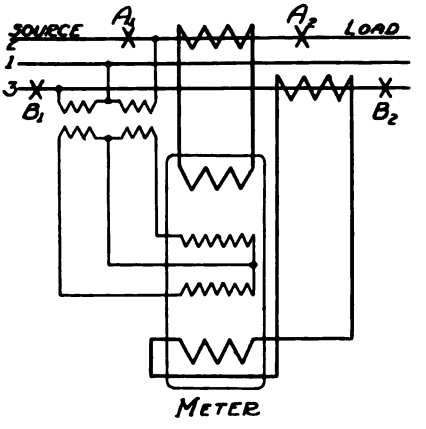


Fig. 2.—Illustration of Check No. 1.

Step 6. Note direction of rotation of disc.

Step 7. Close the line at the points opened in Step 5.

Interpretation:

Rule 1. If the rotation in both Steps 3 and 6 is forward the meter is correctly connected.

Rule 2. If either Step 3 or Step 6 shows reversed rotation, either the current or the voltage coil of the element left in the circuit should be reversed.

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Advantages:

1. The test is effective on any class of meter with or without balanced load, and at any power factor leading or lagging.
2. The leads do not have to be traced.

Disadvantages:

1. Only rarely is it possible from a mechanical standpoint to open a main line in two places.
2. Even if it is possible from this standpoint to open the line, it often happens that it is impracticable to interrupt the load.

CHECK NO. 2

THE ACHERMAN CHECK

Special Apparatus: None.

Procedure:

Step 1. Be sure meter is either class B, E, or F.

Step 2. Be sure the proper current and potential circuits are combined in the same meter element.

Step 3. So connect the current leads to their respective meter coils as to obtain forward rotation for the meter as a whole.

Step 4. Be sure that the load is not badly unbalanced. The difference between the largest and the smallest line currents should not be more than 25 per cent of the smallest.

Step 5. Open the common voltage lead (P_2 Fig. 3) but leave the two meter potential coils strapped together as shown in Fig. 3.

Step 6. Note direction of rotation.

Step 7. Replace the common potential lead P_2.

Interpretation:

Rule 1. If Step 6 gives forward rotation the meter is correctly connected.

Rule 2. If Step 6 gives backward rotation the meter is improperly connected.

Rule 3. To correct the connections reopen the common potential lead P_2 and reverse that current coil that will give forward rotation and then replace the common potential lead P_2.

Rule 4. If now the lightly loaded element by itself rotates backwards the power factor is less than 50 per cent, and if it rotates forward it is greater than 50 per cent.

Advantages:

1. No special apparatus is required.
2. Exact load balance is not required.
3. Knowledge of the power factor is not required.

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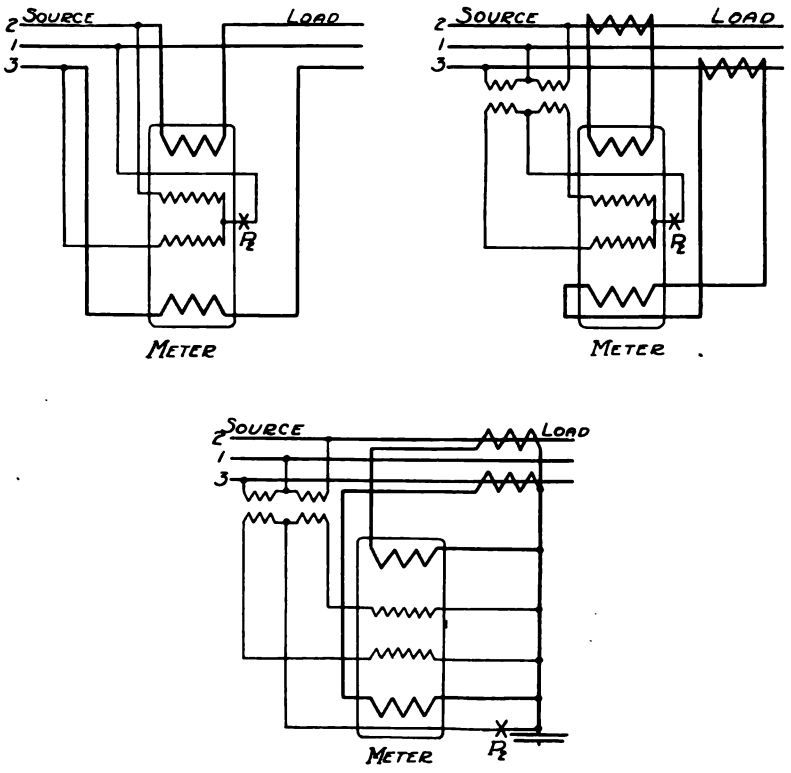


Fig. 3.—Illustration of Check No. 2.

Disadvantages:

1. The leads must be traced.
2. The check is limited to certain classes of connections.

CHECK NO. 3

THE BROWN CHECK

Special Apparatus: A high non-inductive resistance of 10,000 ohms or more.

Procedure:

Step 1. Be sure the load is approximately balanced.

Step 2. Determine whether the power factor is leading or lagging.

Step 3. Be sure the proper current and potential elements are combined in the same meter element.

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Step 4. So connect the current leads to their respective current coils as to obtain forward rotation for the meter as a whole.

Step 5. Determine which is the heavily loaded or fast moving element by opening each potential circuit in turn.

Step 6. Disconnect the fast moving element by opening its potential circuit.

Step 7. Insert the high resistance in series with the potential coil of the slow moving element. (See Fig. 4.)

Step 8. Note the direction of the rotation of the disc.

Step 9. Remove the high resistance and replace all leads.

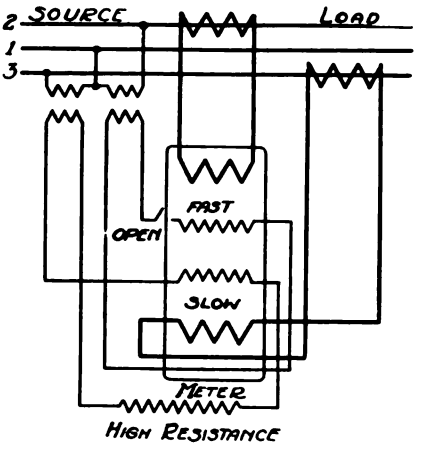


Fig. 4.—Illustration of Check No. 3.

Interpretation:

Rule 1. If Step 2 shows a lagging power factor and Step 8 backward rotation, the meter is correctly connected.

Rule 2. If Step 2 shows a leading power factor and Step 8 forward rotation, the meter is correctly connected.

Rule 3. If in Rule 1 the meter rotates forward and in Rule 2 backwards it is improperly connected.

Advantage:

1. Effective on any Class of meter but Class C.

Disadvantages:

1. Special apparatus is needed.
2. Some lead tracing is necessary.
3. Some knowledge of the power factor is required.

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4. Difficulty in determining the fast and slow elements at power factors near unity.
5. Approximate load balance is required.

CHECK NO. 4

THE KOUWENHOVEN CHECK

Special Apparatus: None.

Procedure:

Step 1. Be sure the load is approximately balanced.

Step 2. Determine which class of connections are used.

Step 3. Determine the two potential leads that are connected to the line wires that furnish current to the current coils. (See Figs. 5 and 6, leads x and y.)

Step 4. Be sure that the common potential leads are not connected to the same coil as in Figs. 5 and 6 (d).

Step 5. Be sure that the common potential leads are not connected to a line wire that furnishes current to a current coil as in Figs. 5 and 6 (e).

Step 6. Interchange leads x and y, as found in Step 3, at the meter for Classes A and B and on the primary side of the potential transformers for Classes D, E and F.

Step 7. Note the speed of rotation, if any.

NOTE: For Class A meters Steps 4 and 5 may be omitted. For Class B, E and F meters Steps 4 and 5 reduce to making sure that the common potential lead P_2 is connected to the proper line wire.

Interpretation:

Rule 1. If after Step 7 the meter stops or runs very slowly in either direction the meter is correctly connected.

Rule 2. If after Step 7 the meter runs forward at increased speed, restore the voltage connections as they were originally before Step 7 and reverse that current coil that will give forward rotation after reversal.

Rule 3. If after Step 7 the rotation is forward at reduced speed, in the neighborhood of ½, leave the voltage connections as they are after Step 7 and reverse that current coil that will give forward rotation after reversal.

Rule 4. If the meter rotates backwards at any appreciable speed after Step 7 the connections are hopelessly wrong and the meter should be entirely rewired.

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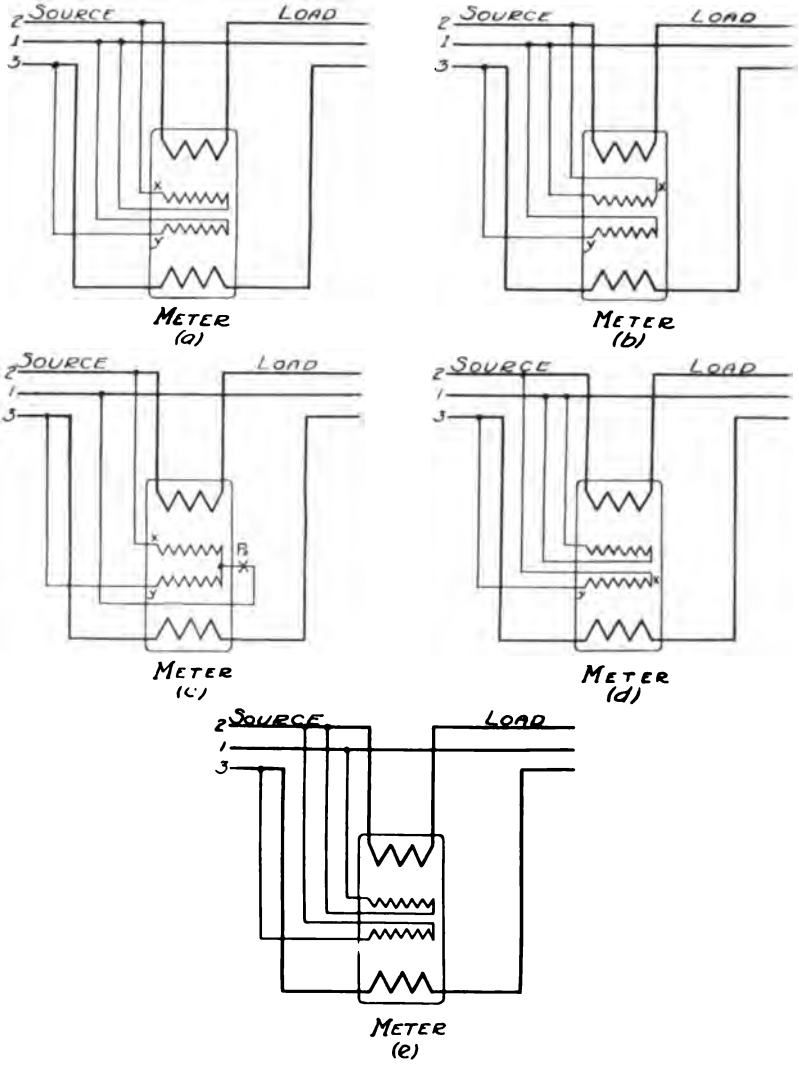


Fig. 5.—Illustration of Check No. 4.

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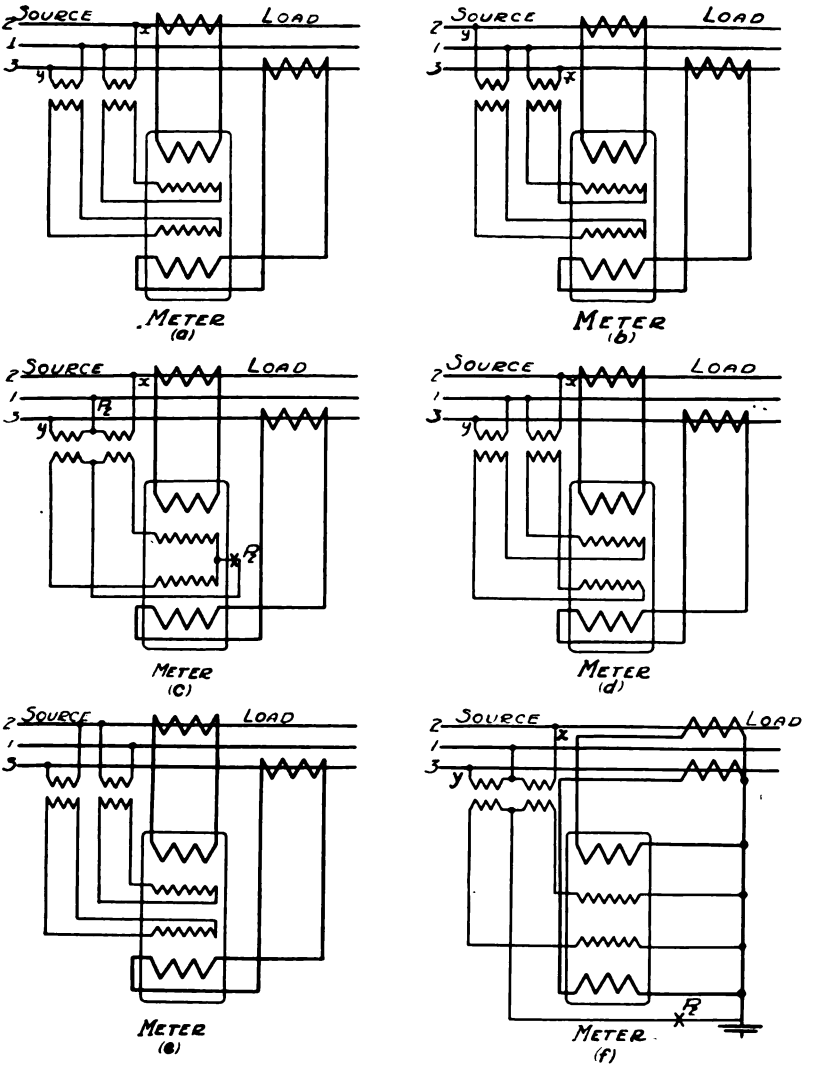


Fig. 6.—Illustration of Check No. 4.

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Advantages:

1. No knowledge of the power factor is required.
2. Information is available to correct the connections should they prove to be wrong.

Disadvantages:

1. Considerable lead tracing is necessary.
2. Approximate load balance is required.

NOTE: By modifying Rule 1 slightly and excluding Rules 2, 3 and 4, this check may be used on unbalanced circuits, but the conditions surrounding its application under such circumstances are so numerous and complex that it has not been included in this manual.

CHECK NO. 5

FOR CLASS C METERS

Special Apparatus: Stop watch.

Procedure:

Step 1. Connect the meter so that it rotates in the forward direction with all leads intact.

Step 2. Be sure the load remains constant during the time of making the check.

Step 3. Time one revolution of the disc.

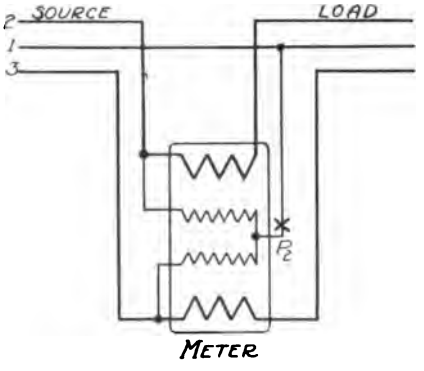


Fig. 7.—Illustration of Check No. 5.

Step 4. Open the common potention lead P_2 Fig. 7, at a point as shown so that the two potential coils are still strapped together.

Step 5. Note the direction of the rotation of the disc.

Step 6. Time one revolution of the disc.

Step 7. Replace lead P_2.

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Interpretation:

Rule 1. If Step 5 shows forward rotation and if in Step 6 the time is approximately twice that in Step 3, the meter is correctly connected.

Rule 2. If the meter does anything else, it is improperly connected.

Advantages:

1. No knowledge of the power factor is required.
2. It is not necessary that the load shall be balanced.

Disadvantages:

1. Some lead tracing is necessary.
2. The load must remain constant while the check is being made.

CHECK NO. 6

THE JONES CHECK

Special Apparatus: 1. A 25-watt lamp. 2. A stop watch. 3. Figs. 9 and 10. 4. Tables 1, 2 and 3. See pages 15, 16, 18 and 19.

Procedure:

Step 1. Be sure that the load is approximately balanced.

Step 2. So connect the current leads to their respective current coils as to obtain forward rotation for the meter as a whole.

Step. 3. If less than 8 leads are brought into the meter one or more of them will be common leads to both elements, current or voltage as the case may be. This may result in such connections as (c) and (d) of Fig. 8, if the wrong wire should be chosen for the common potential or common current lead. These connections must be eliminated.

For the case of Fig. 8 (c) the simplest method is to place the 25-watt lamp, first, from **a** to **b**, and then **c** to **b**, and if it burns with the same brilliancy in both cases, lead **b** is the right common lead. If in one case the lamp is very much brighter than in the other, the wrong lead was assumed to be common.

For a case such as is shown in Fig. 8 (d), short each meter element current coil in turn and if the meter stops in either case, the wrong lead was assumed to be common. If the meter does not stop while either coil is short circuited, then the lead assumed to be common to both coils is the proper lead.

Step 4. Open the bottom element potential circuit.

Step 5. Time one revolution of the disc.

Step 6. Close the bottom element potential circuit.

Step 7. Open the top element potential circuit.

Step 8. Time one revolution of the disc.

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Step 9. Interchange potential leads. That is, put those leads that were on the top element on the bottom and those that were on the bottom on the top. [(See Fig. 8 (a) and (b).]

NOTE: Care must be exercised at this point not to inadvertently assume the wrong common lead again. If there is any doubt repeat Step 3.

Step 10. Open the bottom element potential circuit.

Step 11. Time one revolution of the disc.

Step 12. Close the bottom element potential circuit.

Step 13. Open the top element potential circuit.

Step 14. Time one revolution of the disc.

Step 15. If Steps 5 and 8 are approximately equal, insert the lamp in series with the top potential element with the leads left as they were after Step 9.

Step 16. If Steps 11 and 14 are the ones that are approximately equal, change the potential leads back to their original positions be-

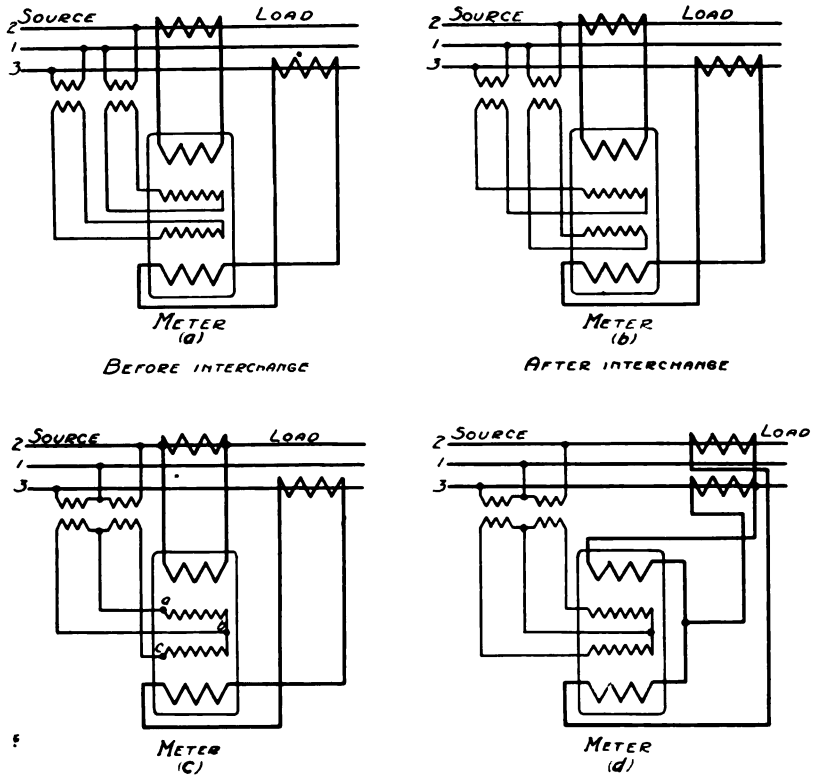


Fig. 8.—Illustration of Check No. 6.

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fore Step 9 and then insert the lamp in series with the top potential element.

Step 17. Open the bottom potential element.

Step 18. Time one revolution of the disc.

Step 19. Insert the lamp in series with the bottom potential element.

Step 20. Open the top element potential circuit.

Step 21. Time one revolution of the disc.

Step 22. Change Steps 5, 8, 11, 14, 18 and 21 to revolutions per minute.

Interpretation:

Rule 1. In Step 22 one set of values, either those resulting from Steps 5 and 8, or Steps 11 and 14, will give speeds approximately equal.

Rule 2. Take that pair that are not approximately equal and divide the slow one by the fast one. This will give ratio A_1 Table 2.

Rule 3. Take the fast one of this pair and divide it by the average of the pair that are nearly equal. This will give ratio B, Table 2.

TABLE 1.—POSSIBLE GROUPS FOR CHECK NO. 6.

	If the speeds of the two meter elements are different	If the speeds of the two meter elements are approximately equal
Group 1	Only correct grouping $E_{12}\ I_2 \cos (30 + \Theta)$ $-E_{31}\ I_3 \cos (30 - \Theta)$	$E_{31}\ I_2 \cos (90 - \Theta)$ $E_{12}\ I_3 \cos (90 - \Theta)$
Group 2	$-E_{23}\ I_2 \cos (30 - \Theta)$ $E_{12}\ I_3 \cos (90 - \Theta)$	$E_{12}\ I_2 \cos (30 + \Theta)$ $E_{23}\ I_3 \cos (30 + \Theta)$
Group 3	$E_{31}\ I_2 \cos (90 - \Theta)$ $E_{23}\ I_3 \cos (30 + \Theta)$	$-E_{23}\ I_2 \cos (30 - \Theta)$ $-E_{31}\ I_3 \cos (30 - \Theta)$

TABLE 2.—POSSIBLE COMBINATIONS FOR CHECK NO. 6.

Combination	Combination I		Combination II		Combination III		Angle
Ratio	A	B	A	B	A	B	Θ
	.000	1.00	1.000	∞	0.000	1.000	0
	.058	1.06	0.942	7.00	0.062	0.942	3
	.114	1.13	0.885	8.77	0.129	0.885	6
	.167	1.20	0.832	5.99	0.202	0.832	9
	.219	1.28	0.781	4.57	0.280	0.781	12
	.268	1.37	0.732	3.73	0.366	0.732	15
	.326	1.46	0.684	3.07	0.462	0.684	18
	.362	1.57	0.636	2.76	0.570	0.636	21
	.410	1.69	0.592	2.44	0.692	0.592	24
	.454	1.84	0.545	2.20	0.833	0.545	27
	.500	2.00	0.500	2.00	1.000	0.500	30

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TABLE 3.—ZONE GROUPINGS FOR CHECK NO. 6.

Combination I	Combination II	Combination III	Zone
Group 3	Group 2	Group 1	A 1
" 1	" 2	" 3	A 2
" 2	" 1	" 3	A 3
" 3	" 1	" 1	B 3
" 1	" 3	" 2	B 2
" 2	" 3	" 2	B 1

Rule 4. From the values of the ratios A and B found above determine the combination which contains such a pair of ratios and the nearest value of the angle Θ. Using table 2.

Rule 5. Make a table of five columns headed as follows:

1 No.	2 Zones	3 Groups	4 Power Factors	5 Angle expressions for cosine values
1	A 1			
2	A 2			
3	A 3			
4	B 3			
5	B 2			
6	B 1			

Rule 6. Having determined the combination by Rule 4, obtain the groups from Table 3 and place them in their proper order in column 3 above.

Rule 7. With the value of Θ as found in Rule 4 and Fig. 10 determine the power factor for each zone and place it in the right order in column 4 above.

Rule 8. By the use of Table 1 (unlike speed values) place in column 5 above, the angle expressions for the groups in column 3.

Rule 9. By the speeds found in Step 22 resulting from Steps 18 and 21 we can determine the effect of DECREASING the power factor upon the speeds of the fast and slow elements—that is, whether they speed up or slow down.

Rule 10. Taking this effect to Fig. 9, together with the angle expressions in the table of Rule 5, and remembering that the fast element always has the highest value of the cosine and that the angle Θ increases as the power factor decreases, determine which of the two group 1's will satisfy this effect. Repeat for the group 2's and 3's (see examples pages 17 and 21).

Rule 11. Discard all those not applying.

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Rule 12. To distinguish between the remaining possibilities (in general three), use must be made of the tester's knowledge of local load conditions. (*See examples pages 17 and 21.*)

Rule 13. Having decided which of the three in Rule 12 meets local conditions, use Table 1 and the fact that for power factors below 50 per cent the slow element should tend to rotate backwards, and for power factors above 50 per cent, it should rotate forward, while in both cases the fast element should rotate forward, to make the necessary corrections.

Advantages:

1. Absolutely no knowledge of the Class of meter or its connections is necessary.
2. Therefore no lead tracing is required.

Disadvantages:

1. This check is somewhat complicated.
2. Special charts and apparatus are required.
3. Some knowledge of the power factor is essential.
4. A balanced load is necessary.
5. Some difficulty may be experienced in differentiating between the fast and slow elements at power factors near unity.

The following examples will help to illustrate Check No. 6:

EXAMPLE 1

In a certain meter installation Step 5 gave 19 sec.
" 8 " 17 sec.
" 11 " 24 sec.
" 14 " 49 sec.

Since Steps 5 and 8 are approximately equal Step 15 applies, and Step 18 gave 33 sec.
" 21 " 32 sec.

Step 22 gives the following:

From Step 5 Top element before interchange $= \frac{60}{19} = 3.16$ R.P.M.

From Step 8 Bottom element before interchange $= \frac{60}{17} = 3.53$ R.P.M.

From Step 11 Top element after interchange $= \frac{60}{24} = 2.50$ R.P.M.

From Step 14 Bottom element after interchange $= \frac{60}{49} = 1.22$ R.P.M.

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From Step 18 Top element with lamp $= \frac{60}{33} = 1.82$ R.P.M.

From Step 21 Bottom element with lamp $= \frac{60}{32} = 1.88$ R.P.M.

As stated in Rule 1 we find Steps 5 and 8 approximately equal. Therefore, according to Rule 2 we take the values resulting from

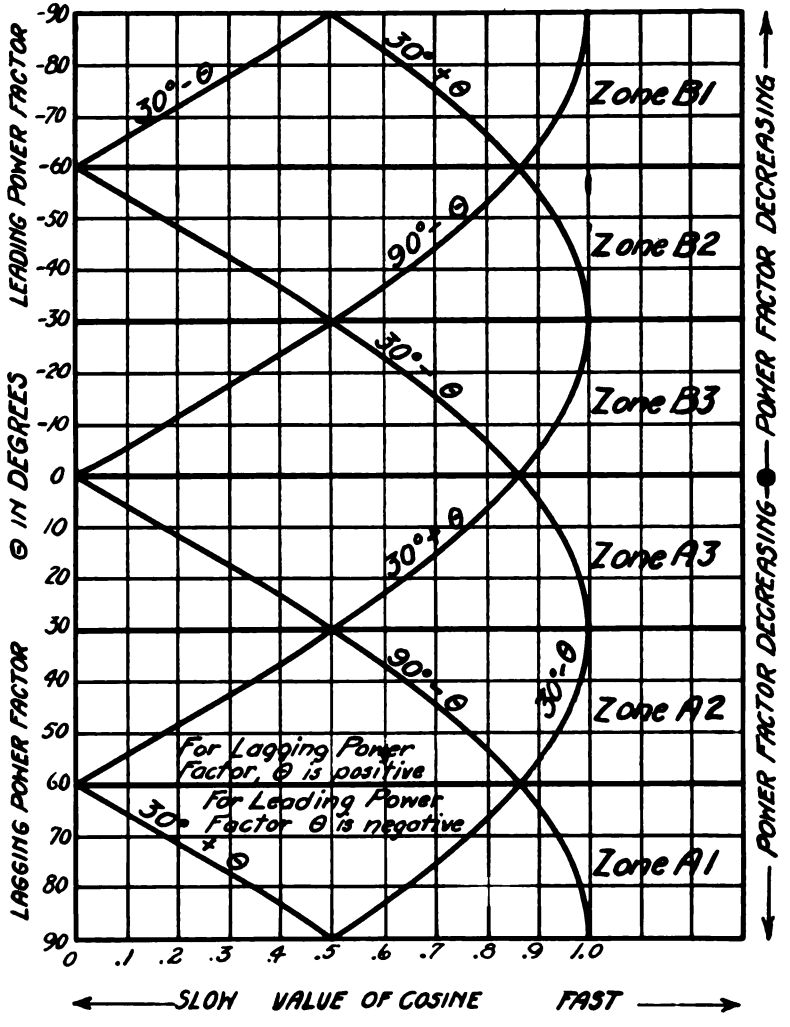


Fig. 9.—Curves for Use with Check No. 6.

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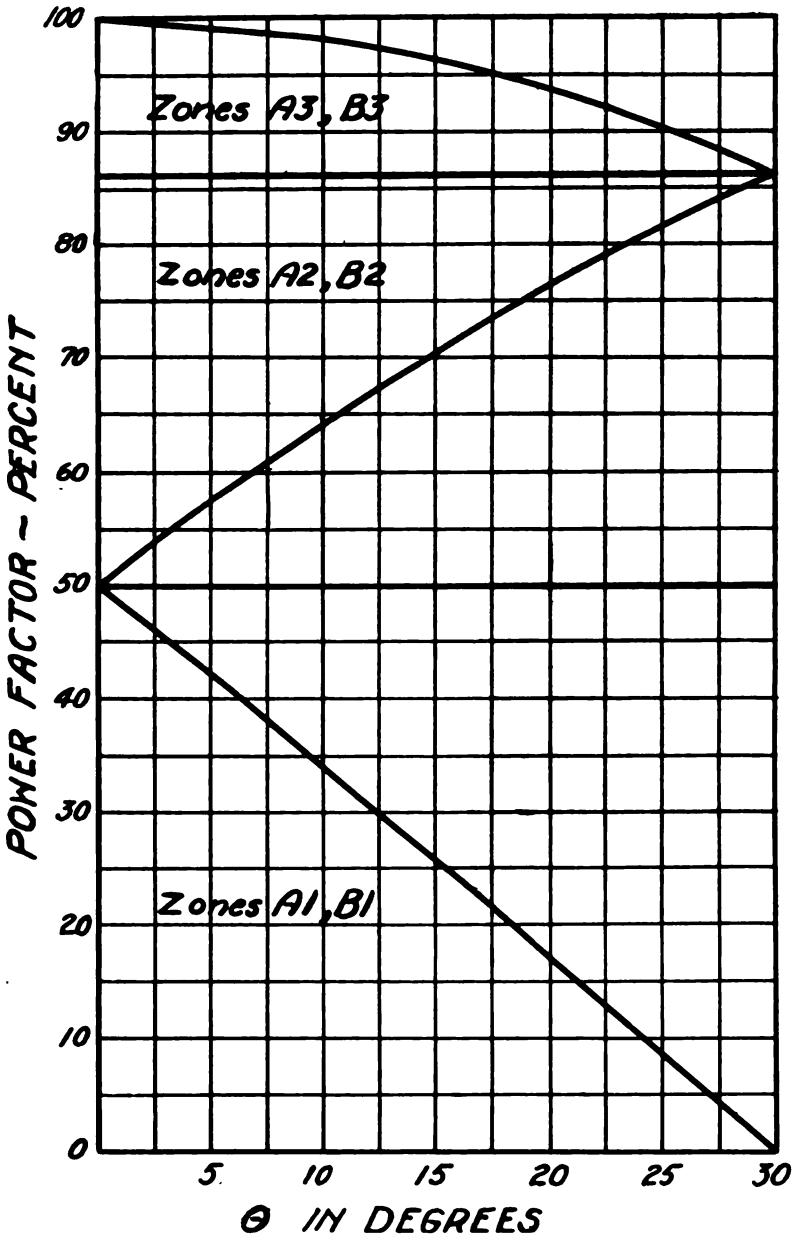


Fig. 10.—Curves for Use with Check No. 6.

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Steps 11 and 14. This gives ratio $A = \frac{1.22}{2.5} = 0.49$.

Applying rule 3 we find the average of Steps 5 and 8 as follows:

$3.16 + 3.53 = 6.69$. Av. $= \frac{6.69}{2} = 3.34$.

Therefore ratio $B = \frac{2.5}{3.34} = 0.75$.

Applying Rule 4, we see from Table 2 that the only combination that contains such a pair of ratios is Combination III at about 19°.

Applying Rule 5, we draw up the following table:

1 No.	2 Zones	3 Groups	4 Power Factor	5 Angle Expressions for cosine values
1	A 1	1	20%	$(30 + \Theta)$, $(30 - \Theta)$
2	A 2	3	75%	$(90 - \Theta)$, $(30 + \Theta)$
3	A 3	3	95%	$(90 - \Theta)$, $(30 + \Theta)$
4	B 3	1	95%	$(30 + \Theta)$, $(30 - \Theta)$
5	B 2	2	75%	$(30 - \Theta)$, $(90 - \Theta)$
6	B 1	2	20%	$(30 - \Theta)$, $(90 - \Theta)$

Applying Rule 6, by taking Combination III to Table 3 we get column 3 above.

Applying Rule 7, by taking $\Theta = 19°$ to Fig. 10 and from the curves obtain the power factor possible for each zone. These we arrange in column 4.

Applying Rule 8, by taking column 3 above to the first column of Table 1 we obtain the angle expressions for column 5.

Applying Rule 9, we note from the speeds given in Step 22 from the values of Steps 18 and 21 that 1.82 is slower than 2.5 and that 1.88 is faster than 1.22. Therefore, the effect of *decreasing* the power factor is to slow down the fast element and speed up the slow element.

Rules 10 and 11. From the table in Rule 5 we see that we must first distinguish between group 1 in zone A 1 and group 1 in zone B 3, then, group 3 in zone A 2 and group 3 in zone A 3, and finally, group 2 in zone B 2 and group 2 in zone B 1. Taking the first pair we see, from column 5 of the table, that the angle expressions for group 1 are $(30 + \Theta)$ and $(30 - \Theta)$. Turning to Fig. 9 we see that the curve $(30 - \Theta)$ has a higher value for its cosine in zone A 1 than does the curve $(30 + \Theta)$ but in zone B 3 the opposite is the case. Thus in zone A 1 the fast element corresponds to the expression $(30 - \Theta)$, but in zone B 3 the fast element corresponds to

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$(30 + \Theta)$. In zone A 1 the fast element curve slows down as the power factor angle increases from 60 to 90 (power factor decreasing) while the slow element curve corresponding to the expression $(30 + \Theta)$ speeds up in zone A 1. This satisfies the effect found in Rule 9. In zone B 3 we find just the opposite taking place. The fast element curve which now corresponds to $(30 + \Theta)$ speeds up as the angle changes from 0 to —30 and the slow element curve corresponding to the expression $(30 - \Theta)$ slows down. It is obvious that this is just opposite to the effect found in Rule 9. Therefore, we may safely discard the zone B 3 possibility in favor of the zone A 1. In like manner we proceed with the second pair, group 3 in zones A 2, and A 3, and we find that the fast element curve $(90 - \Theta)$ in zone A_2 speeds up and the slow element curve $(30 + \Theta)$ slows down which is contrary to the effect of Rule 9. In zone A 3 on the other hand we find the curve $(30 + \Theta)$ corresponding to the fast element decreasing, and the curve $(90 - \Theta)$ corresponding to the slow element increasing, which satisfies the effect found by Rule 9. Consequently we may safely discard zone A 2. In the same manner we find that zone B 2 can safely be discarded.

Rule 12. We now have left in our table of Rule 5

No. 1 at 20 per cent power factor lagging,

No. 3 at 95 per cent power factor lagging, and

No. 6 at 20 per cent power factor leading.

To distinguish between these three we have to draw upon our knowledge of local load conditions. In this particular case the load was an induction motor running idle and we, therefore, know that the power factor was below 50 per cent lagging. Therefore No. 1 is the actual meter connection.

Rule 13. Since the speeds of the elements were alike originally we see from Table 1 that to change group 1, like speeds, to group 1, unlike speeds, we have to interchange the voltage leads. That is, put those leads that were on the bottom element on the top element. Also, since the power factor is below 50 per cent, so connect the voltage leads to the slow element that it rotates backwards.

We may now pronounce the meter correctly connected.

EXAMPLE 2

In a certain meter installation Step 5 gave 26 sec.
" 8 " 8 sec.
" 11 " 15 sec.
" 14 " 15 sec.

Since Steps 11 and 14 are now the ones that are approximately equal, Step 16 applies.

Step 18 gave 115 sec.
" 21 " 10 sec.

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Step 22 gives the following:

From Step 5 Top element before interchange $= \frac{60}{26} = 2.3$ R.P.M.

From Step 8 Bottom element before interchange $= \frac{60}{8} = 7.5$ R.P.M.

From Step 11 Top element after interchange $= \frac{60}{15} = 4.0$ R.P.M.

From Step 14 Bottom element after interchange $= \frac{60}{15} = 4.0$ R.P.M.

From Step 18 Top element with lamp $= \frac{60}{115} = 0.52$ R.P.M.

From Step 21 Bottom element with lamp $= \frac{60}{10} = 6.0$ R.P.M.

As stated in Rule 1, we find Steps 11 and 14 approximately equal. Therefore, according to Rule 2, we take the values resulting from Steps 5 and 8. This gives ratio $A = \frac{2.3}{7.5} = 0.307$.

Applying Rule 3 we find ratio $B = \frac{7.5}{4} = 1.87$

Applying Rule 4, we see from Table 2 that the only combination that contains such a pair of ratios is Combination I at about 16°.

Applying Rule 5, we draw up the following table:

1 No.	2 Zones	3 Groups	4 Power Factor	5 Angle Expressions for cosine values
1	A 1	3	25%	$(90 - \Theta)$, $(30 + \Theta)$
2	A 2	1	71%	$(30 - \Theta)$, $(30 + \Theta)$
3	A 3	2	96%	$(30 - \Theta)$, $(90 - \Theta)$
4	B 3	3	96%	$(90 - \Theta)$, $(30 + \Theta)$
5	B 2	1	71%	$(30 - \Theta)$, $(30 + \Theta)$
6	B 1	2	25%	$(30 - \Theta)$, $(90 - \Theta)$

Applying Rule 6, by taking Combination I to Table 3 we get column 3 above.

Applying Rule 7, by taking $\Theta = 16°$ to Fig. 10 and from the curves obtain the power factors possible in each zone. These we arrange in column 4.

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Applying Rule 8, by taking column 3 above to the first column of Table 1 we obtain the angle expressions for column 5.

Applying Rule 9, we note from the speeds given in Step 22 from the values of Steps 18 and 21 that 0.52 is slower than 2.3 and that 6.0 is slower than 7.5. Therefore the effect of *decreasing* the power factor is to slow down both the fast and the slow element.

Rules 10 and 11. From the table in Rule 5 we see that we must first distinguish between group 3 in zone A 1 and group 3 in zone B 3, then, group 1 in zone A 2 and group 1 in zone B 2, and finally group 2 in zone A 3 and group 2 in zone B 1. Taking the first pair we see from column 5 of the table that the angle expressions for group 3 are $(90 - \Theta)$ and $(30 + \Theta)$. Turning to Fig. 9, we see that the curve $(90 - \Theta)$ has a higher value of its cosine in zone A 1 than does $(30 + \Theta)$, but in zone B 3 the opposite is the case. Thus in zone A 1 the fast element corresponds to the expression $(90 - \Theta)$, but in zone B 3 the fast element corresponds to the expression $(30 + \Theta)$. In zone A 1 the fast element curve $(90 - \Theta)$ speeds up and the slow element curve $(30 + \Theta)$ also speeds up as the power factor angle increases from 60 to 90 (power factor decreasing). This is contrary to the effect found in Rule 9. In zone B 3 we find again the same thing. The fast element curve $(30 + \Theta)$ and the slow element curve $(90 - \Theta)$ both speed up as the power factor angle increases from 0 to —30. Therefore we discard both of these possibilities.

In like manner we proceed with the second pair, group 1 in zone A 2 and group 1 in zone B 2, and we find that the fast element curve $(30 - \Theta)$ in zone A 2 and the slow element curve $(30 + \Theta)$ in zone A 2 both decrease as the power factor angle increases from 30 to 60. This satisfies the effect found in Rule 9. In zone B 2 we find that the slow element curve $(30 - \Theta)$ and the fast element curve $(30 + \Theta)$ both decrease in speed as the power factor angle increases from — 30 to — 60. This again satisfies the effect of Rule 9. Therefore we retain both of these values.

In the same manner we proceed with the third pair in zones A 3 and B 1, and find that we can discard both of them, as in neither zone do they satisfy the effect of Rule 9.

Rule 12. We now have left in our table of Rule 5

No. 2 at 71 per cent power factor lagging, and

No. 5 at 71 per cent power factor leading.

To distinguish between these two we have to draw upon our knowledge of local load conditions. In this particular case the load was an induction motor. Therefore we know that a leading power factor is impossible, and that No. 2 is our actual meter connection.

Rule 13. Since the speed of the elements were unlike originally, we see from Table 1 that as far as the voltage leads are concerned

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the meter was correct, and now since we have determined that the power factor is above 50 per cent, we make sure that both elements run forward when connected independently and pronounce our meter correctly connected.

CONCLUSIONS

The best check to use in any given case as seen from the advantages and disadvantages listed under each check will depend upon local conditions, such as:

1. Class of meter.
2. Accessibility of installation.
3. Whether or not the leads can be traced.
4. Knowledge of load power factor.
5. Knowledge of load balance.
   (a) Degree of unbalance, if any.
6. Amount of interruption and disturbance of load allowable.
7. Amount of special apparatus obtainable.

If we assume total ignorance of all these factors and the impracticability of interrupting the load, we have only one course of action. Put jumpers around the entire installation, tag all leads, and remove both meter and instrument transformers to the laboratory where a thorough check may be made.

If we assume total ignorance of all these factors but it is practicable to open one line at a time, then Check No. 1 is the logical one to use.

If we assume inability to trace the leads, such as in remote metering, but have some knowledge of the load power factor and know that the load is approximately balanced, Check No. 6 is the best choice.

If the load is badly unbalanced, Check No. 1 is the only satisfactory check, (Except class C meters).

If the load is partially unbalanced Check No. 2 may be used within certain limits.

If the meter is of the right class and the other conditions are complied with, Check No. 2 will be found most satisfactory for general use, especially in checking new installations.

For checking old installations where all leads are accessible, Check No. 4 has the advantage in that it furnishes the information for making the corrections.

For Class C meters Check No. 5 will satisfy almost every possibility. If the load cannot be held constant for a long enough period to perform the test, Check No. 1 may be used.

Of course any number of different checks may be applied to a given meter if the conditions are satisfactory, and one used as a check on another.

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Reconstruction
OF
Old Gravel Roads

By

C. C. ALBRIGHT
and
R. E. MILLS



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LAFAYETTE, INDIANA

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BULLETIN NO. 9
ENGINEERING EXTENSION SERVICE

Reconstruction of Old Gravel Roads

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PURDUE UNIVERSITY
LAFAYETTE, INDIANA
JANUARY, 1925

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RECONSTRUCTION OF OLD GRAVEL ROADS

INTRODUCTION

Practically the entire United States is now engaged in an extensive program of highway construction and maintenance. The total amount of money spent in 1921 in this program is shown in Table 1. The data in this table were taken from an article published in the Roads and Streets edition of Engineering and Contracting, February, 1925, by Henry R. Trumbower, Economist, United States Bureau of Public Roads. Probably twenty-five to thirty per cent of

TABLE I.

TOTAL EXPENDITURES FOR RURAL HIGHWAY PURPOSES—1921

By States, Counties, Townships and Districts

Construction Roads and Bridges	**$ 626,965,373**
Maintenance Roads and Bridges	**248,593,169**
Administration and Engineering	**36,031,353**
Principal and Interest Payments	**89,280,946**
General and Miscellaneous (Purchase and repair of equipment)	**35,716,931**
Total	**$1,036,587,772**

this total amount is spent for maintenance and reconstruction and doubtless much of this money could be saved with an increased knowledge of methods and materials.

Indiana is fortunate in having widely distributed resources in good gravel and stone for road building. Most of the early roads were surfaced with gravel which could be secured with the least effort and cost. Unfortunately, however, a majority of the early roads were constructed with little knowledge of the fundamentals of engineering involved. The development of the motor vehicle in the last two decades has introduced new highway problems which could not have been foreseen. As a consequence, one of the great problems today is the reconstruction of many of our roads, so that they can accommodate the new traffic and be maintained more efficiently.

The experimental work described in this bulletin was undertaken in order to demonstrate the economic possibilities of new methods of maintenance reconstruction of gravel roads. The methods are not entirely new, but are the result of experience with improved equipment in recent years. In the past similar work using hand labor and horse-drawn equipment has been so expensive that little progress was made.

This work was planned as an activity of the Engineering Extension Service of Purdue University, and was made possible through

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the cooperation of Mr. W. E. Gove, Road Superintendent of Tippecanoe County, who supplied a 10-ton Holt caterpillar tractor with operator, and J. D. Adams and Company, Indianapolis, who furnished a 12-foot adjustable leaning wheel grader with an operator.

The general plan of the work is reviewed in this bulletin by Professor C. C. Albright of the School of Civil Engineering. The field observations and compilation of data were made by Mr. R. E. Mills, Research Assistant in the Purdue Engineering Experiment Station.

METHOD OF RECONSTRUCTION

The road selected for this experiment is located in the southeast part of Tippecanoe County about 12 miles from Lafayette, the county seat. The general character of the topography is smooth with very flat slopes, as is clearly illustrated by Figures 2 and 17. The sides of the road were covered with a dense growth of grass, weeds and in some places brush. A portion of these were cut and burned. The larger shrubs up to four or five inches in diameter were pulled out or cut off by the grader blade. The tractor had ample power and the grader sufficient strength to do this.

In operations of the kind described in this bulletin the vegetation may be cut prior to the work of grading. However light growths can be removed more economically by the grader. Brush or trees too large for this operation should be either pulled out by the tractor or cut and removed from the road.

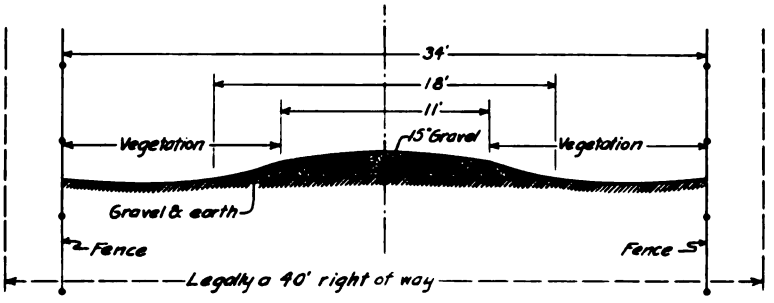


Figure 1.—Typical Cross-Section of Old Road.

A typical cross-section of the road is shown in Figure 1. The ground was practically flat between the fences which were 34 feet apart. A width of about 11 feet of gravel surface was exposed, the remainder of the road being covered with vegetation. Test pits indicated a 15-inch depth of gravel in the center of the road, 11 inches at 5½ feet out and feathering to zero depth at 9 feet out. The original earth subgrade was crowned about two inches. There were practically no side ditches.

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Figure 2.—Mowing Grass and Weeds.

In figures 2 and 3 the grass and weeds are being cut and burned prior to grading. This should always be done when there is a heavy growth of vegetation in order to facilitate grading operations, and to prevent excessive settling with resultant inequalities in the shoulders of the finished road. In no case should the vegetation be cut unless it is to be raked up and either burned or removed from the roadway, for when it is only cut down it bunches up under the grader and is more difficult to handle than if allowed to stand.



Figure 3.—Burning Grass and Weeds.

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Figure 4.—First Round—Throwing Out Sod.

Figure 4 shows the first round of the grader making a light cut of about 3 inches which peels off the sod along the edges of the road and throws it out, thus exposing the gravel. In this round a roadbed was exposed over a maximum width of 21 feet. The first cut should be made as thin as possible, since heavy sod is difficult to break up and cover.

Figure 5 shows the grader on the second round making a cut where the sod has just been removed, the purpose of this cut being to provide a place to bury the sod. The depth of the cut was ten inches.



Figure 5.—Second Round—Throwing Gravel Toward Center.

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Figure 6.—Ditch in Shoulder for Sod.

The loose gravel and earth brought up by the blade of the grader was thrown over on the hard road surface. It might be well to add here that the quality of the reclaimed gravel was better than is indicated in the illustration. Care should be exercised, however, to prevent too much earth being thrown up with the gravel.

Figure 6 is a view of the ditch which has just been cut as a place to bury the sod. On the right is the reclaimed road metal and on the left is the sod.



Figure 7.—Third Round—Moving Sod into

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Figure 8.—Fourth Round—First Cut for Side Ditch.

Figure 7 shows the grader on its third round. The blade catches the loose sod, as well as cutting the sod over the location of the final side ditches, and moves all of it into the ditch shown in Figure 6.

Figure 8 shows the grader on the fourth round, making the first cut for the new side ditches on a line 14½ feet from the center line of the road, which in this case was about 2½ feet in from the fences. The earth was deposited by the heel of the blade on top of the sod shown in Figure 7. On the fifth round the ditch was deepened, the cut being stepped in a little from the previous line. The



Figure 9.—Sixth Round—Back Sloper Finishing Ditch.

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Figure 10.—Seventh Round—Moving Gravel Outward over Shoulder.

caterpillar tractor traveled on the loose sod previously placed breaking and packing it, while the blade carried the fresh earth on top.

Figure 9 taken on the sixth round shows the finishing operation on the ditch with the back sloper attached to the grader. In this operation the ditch was again deepened, the back slope was finished to a 1 to 1 slope, a flat bottom was cut 15 inches wide and the inside face was finished to a 2 to 1 slope.

Figure 10 is a view of the tractor and grader on the seventh round. The back sloper has been removed and the grader is mov-



Figure 11.—Eighth Round—Scarifying G

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Figure 12.—Tenth Round—Smoothing and Finishing Surface.

ing the loose earth and gravel outward over the packed sod on the shoulder. During the several rounds the heavy tractor traveled on the shoulder breaking the sod and packing the sod and fresh earth, so that very little settlement occurred afterward.

After the reclaimed gravel had been spread out on the prepared shoulder base, the grader blade was removed and the scarifier attached as in Figure 11 where it is shown in the eighth round scarifying the hard gravel center of the road to a depth of four inches. Care should be exercised to scarify no deeper than is necessary to



Figure 13.—Finished Road.

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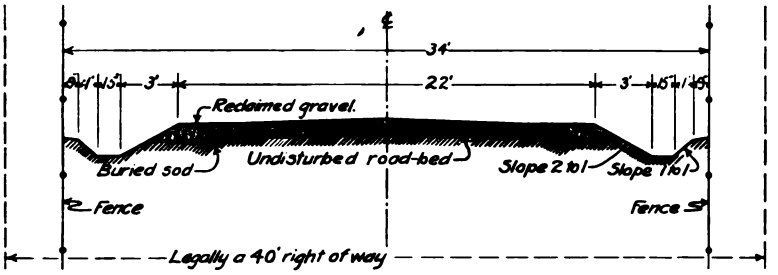


Figure 14.—Typical Cross-Section of Reconstructed Road.

remove the original high crown of the roadway. The same precaution should also be taken when scarifying an old road surface to remove pits and waves, as it is desirable to retain as much as possible of the original firm base.

After completing the scarifying the attachment was removed and the blade again attached. In the ninth round the freshly scarified gravel was moved outward while the tenth round was a smoothing and finishing process, shown in Fig. 12.

Figure 13 is a view and Figure 14 is a cross-section diagram of the completed road with a 22-foot lightly crowned surface and side ditches which are large enough to carry all the surface drainage away quickly from the road bed. No new material has been added, but a sufficient quantity has been reclaimed from the original center which was too highly crowned, and from the shoulders to cover the entire surface. In this process of reclaiming and distributing the gravel, the road has been changed from a narrow one-way lane to a modern highway, adequate for all ordinary two-way traffic. This re-



Figure 15.—Finished Ditch.

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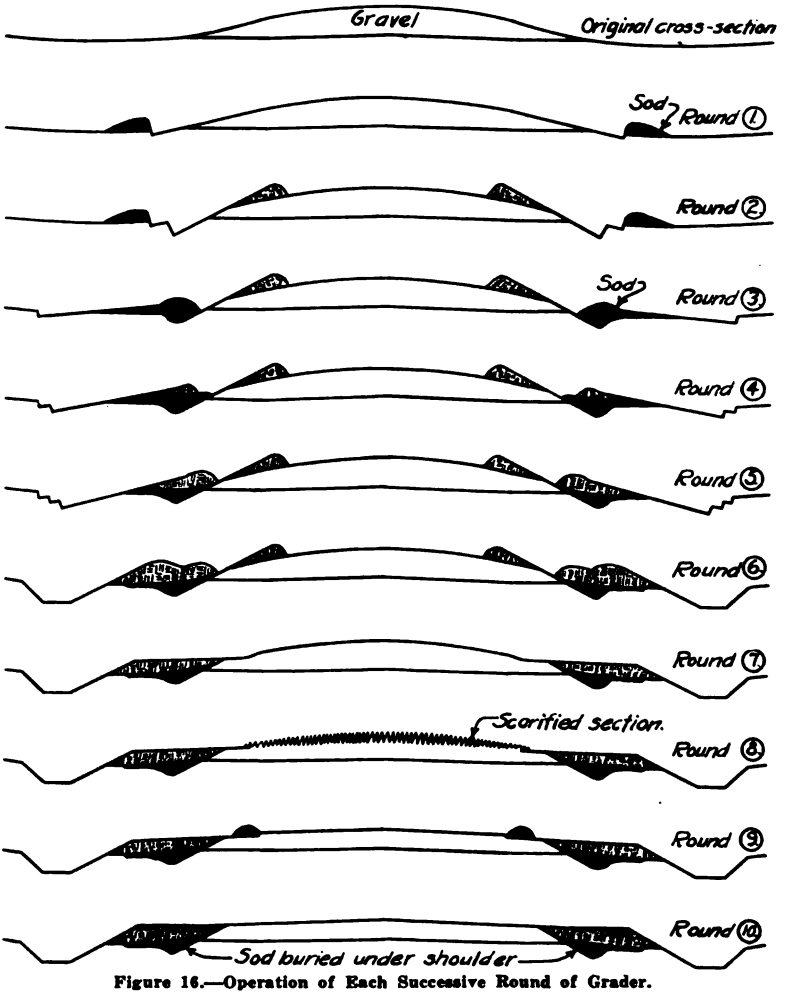


Figure 16.—Operation of Each Successive Round of Grader.

construction will greatly simplify future maintenance consisting mainly of surface dragging and the addition of thin coatings of gravel as needed.

Figure 15 shows the clean cut form of the ditch and shoulders. The slight elevation of the shoulders above the edge of the roadway was given to compensate for the future shrinkage of the buried sod.

The routine of the operation is shown in Figure 16. A diagram of the cross-section after each successive round indicates the order and accomplishment of the various steps. The grader is always operated by rounds, up one side of the road and down the other as each cut serves as a guide for all future rounds.

Figure 17 is a view of the road taken in December, 1923, six months after its completion. It will be noted that the shoulders have settled very little. From observation on this road and consid-

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Figure 17.—Road Six Months after Reconstruction.

eration of other data, only a slight lifting of the shoulders over the buried sod is recommended, as the sod is so thoroughly broken up and packed by a heavy tractor that under ordinary conditions little settlement will afterward occur.

CONCLUSIONS

The methods used on this road appear to be well adapted to the general reconstruction of old gravel roads under conditions similar to those described. It is believed they would be equally successful in the reconstruction of any of the so-called secondary type roads such as cinders, shale or macadam, providing an outfit is used of sufficient size and strength to insure the equipment against overloading. For greater ease in doing the work, it should be undertaken in the spring or early summer, before the vegetation gets heavy and when the road is softened by moisture. It could also be performed to advantage after a rainfall of sufficient duration and amount to soften the road. The early season work has the advantage of superior natural settlement and consolidation prior to the summer traffic season.

A striking observation during the work was the ease and quickness with which the apparently heavy and cumbersome equipment could be turned at the end of a round. It was turned in a circle of diameter equal to length of grader plus one-half the gauge dist. of front wheels. The average time was 30 secon

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The following data is given for this experimental road:

Length, 1425 feet.
Total time grading, 3½ hours.
Gasoline, 20.8 gallons.
Tractor oil, 1 quart.
One driver with team and mowing machine, 1 hour.
Two laborers burning grass and weeds, 2 hours.

It is unfortunate that the length of this experimental road was too short to yield accurate cost data, although it has demonstrated the effectiveness of the methods. It is estimated from the data given that the total cost of the work under similar conditions, including the preliminary labor of cutting and burning grass, weeds and brush and also including interest, depreciation and repairs on equipment would be $50.00 to $75.00 per mile, which represents a very material saving over work performed with hand labor and horse drawn equipment.

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VOL. IX MARCH, 1925 NO. 3

Proceedings
Eleventh Annual Road School

Held at

PURDUE UNIVERSITY

Compiled and Edited by
BEN H. PETTY



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LAFAYETTE, INDIANA

Published by Purdue University at Lafayette, Indiana

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Proceedings

of the

Eleventh Annual Road School

Held at

PURDUE UNIVERSITY

JANUARY 19 to 23, 1925

Under the Direction of
The School of Civil Engineering
With the Co-operation of
The Indiana State Highway Commission,
The Indiana County Highway Superintendents' Association,
The Indiana County Surveyors' and County Engineers' Association,
and
The City Street Commissioners' Association
of the State of Indiana.

Compiled and edited by Ben H. Petty,
Assistant Professor of Highway Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
MARCH, 1925

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(Note:—This paper has been published complete as Engineering Extension Circular No. 7, and is not included in this Proceedings. Copies of this Circular can be secured free of charge by addressing a request to the Engineering Extension Service, Purdue University, Lafayette, Ind.)

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PREFACE

Apparently, the Eleventh Annual Purdue Road School held during the week of January 19-23, 1925, has been the most successful ever held at Purdue, not only in total registration, but also in the merit of the program and the interest displayed by those attending. This success is due in great part to the very fine spirit of co-operation shown by practically every one connected in any way with the activities of the Road School. The classified registration was as follows:

State Highway Commission	53
County Highway Superintendents	77
Assistant County Highway Superintendents	49
County Surveyors and Engineers	30
Assistant County Surveyors and Engineers	3
County Commissioners	19
City Street Commissioners	15
City Engineers	9
Assistant City Engineers	2
Township Trustees	2
Road and Street Contractors	35
Material and Equipment Men	91
Miscellaneous	48
Total	433

This total registration of 433 is 129 more than registered last year, and exceeds by 68 the record attendance of 1922. The attendance on the part of County Surveyors, City Street Commissioners, County Commissioners and Contractors, was greater this year than in former years.

It is very gratifying to note the increased attendance on the part of County Commissioners. There were 19 representatives of this group present this year and they were very much interested in the accomplishments and value of the Road School. It is hoped that attendance on the part of County Commissioners will be greatly increased in the future. The County Highway Superintendent is a four year appointee of the Board of County Commissioners and his work is under its direct supervision. Unless the Commissioners of a county are thoroughly "sold" on the value to the community of adequate road maintenar the County Highway Superintendent will be greatly handicar in his efforts to improve road conditions. Since th

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problem is one of the most important confronting County Commissioners, I believe it would be of very great benefit to the taxpayers of the State, if the Commissioners from each county would regularly attend the annual Purdue Road School.

Mr. W. O. Jones, President of the County Highway Superintendents' Association, started a splendid innovation this year by having the Secretary call the roll of the 92 County Highway Superintendents at the opening of each session of the school. This resulted in a full attendance of this group at practically every session.

Fifteen County Highway Superintendents failed to attend the school this year. Of this number, about five sent in reasonable excuses. These fifteen counties are as follows:

Bartholomew	Elkhart	Jennings	Ohio	Spencer
Blackford	Floyd	Marshall	Owen	Vigo
Brown	Franklin	Monroe	Ripley	Wells

The State Highway Commission was represented by a total of 53 men at different times during the week. Mr. A. B. Burch, vice-chairman of the Commission from Evansville, spoke on the plans of the State Highway Commission for 1925 at the first session of the Road School. Mr. A. H. Hinkle, Superintendent of Maintenance, was present with practically his entire maintenance force down to and including the grade of Sub-District Superintendent. Mr. C. Gray, Chief Engineer, and Mr. W. J. Titus, Bridge Engineer, were also present and took part in the program.

The County Surveyors and Engineers had a total of 30 men present and were deeply interested in the proceedings. This Association is presenting a bill to the present legislature somewhat similar to the bill of the Highway Superintendents, which will authorize their attendance at the Annual Road School with the expenses paid by their respective counties. Our County Surveyors are charged with the duties of making surveys and locations for county road construction, drawing up specifications and plans and supervising the construction. These are vital matters in the county highway program and unless they are in the hands of a competent engineer, will, in many cases, result in the loss of thousands of dollars to the taxpayers of the county. I believe that a compulsory attendance of County Surveyors at the Annual Road School would result in greatly improved county road construction and produce a great saving to the taxpayers.

An innovation this year was the Dinner-Smoker held in the new Purdue Memorial Union Building on Monday evening. Mr. Dick Miller, President of the City Trust Company of Indianapolis, was the principal speaker. The Annual Banquet on Thursday night was attended by about 300 men. Addresses were made

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by Hon. F. Harold Van Orman, Lieutenant Governor; Doctor E. C. Elliott, President of the University, and Dean A. A. Potter, Dean of Engineering Schools, Purdue University.

The County Highway Superintendents elect their officers for terms of two years. This being the mid-year, the old officers will hold over for another year. These officers are as follows:

W. O. Jones, Richmond.....President
Matt Foster, Evansville.....Vice-President
Clyde Piper, Connersville.....Secretary-Treasurer

The newly elected officers of the Indiana County Surveyors' and Engineers' Association are:

Don Heaton, Fowler.....President
George Schmidt, Indianapolis.....Vice-President
C. K. Wallace, Hammond.....Secretary-Treasurer

The City Street Commissioners' Association re elected the officers of last year, as follows:

A. A. Girton, Shelbyville.....President
Charles Buck, Madison.....Vice-President
R. W. Carrettee, East Chicago.....Secretary
W. M. Williams, Newcastle.....Treasurer

The papers, as printed in this volume, have been considerably condensed from the original form in which they were presented at the Road School due to the fact that the funds available for publishing the proceedings are limited. The Editor has endeavored also to eliminate repetition where the speakers discussed similar subjects.

The Annual Road School is under the direction of the School of Civil Engineering and is one of the activities of the Engineering Extension Service of Purdue.

B. H. P.

Lafayette, Indiana.
March, 1925.

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PROGRAM

MONDAY, JANUARY 19, 1925

Morning

Registration at Civil Engineering Building.

Afternoon

Presiding, Dean A. A. Potter, Dean of Engineering and Director of Engineering Extension Service, Purdue University.

Address of Welcome—
Doctor W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Replies—
Mr. Alvan V. Burch, Vice-Chairman, Indiana State Highway Commission.
Mr. W. O. Jones, President, Indiana County Highway Superintendents' Association.
Mr. D. L. Heaton, President, Indiana County Surveyors' and County Engineers' Association.
Mr. A. A. Girton, President, The City Street Commissioners' Association of the State of Indiana.

Announcements—
Professor Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

Highway Safety—
Doctor W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Indiana's State Highway Program for 1925—
Mr. Alvan V. Burch, Vice-Chairman, Indiana State Highway Commission.

TUESDAY, JANUARY 20, 1925

Morning

Presiding, Mr. A. H. Hinkle, Superintendent of Maintenance, Indiana State Highway Commission.

Maintenance of Macadam Roads with Bituminous Materials—
Mr. V. C. Lee, District Engineer, Indiana State Highway Commission.

Maintenance of Gravel Roads—
Mr. J. T. Donaghey, Chief Engineer, Wisconsin State Highway Commission.

Discussion—
Mr. Matt Foster, Vanderburgh County Highway Superintendent.

Proper Method of Constructing Bituminous Macadam Roads—
Mr. A. O. Hastings, District Engineer, Indiana State Highway Commission.

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Discussion—
Mr. E. B. Lockridge, District Engineer, Indiana State Highway Commission.

Afternoon

Presiding, Mr. W. O. Jones, President, Indiana County Highway Superintendents' Association.

Construction of Concrete Roads—
Professor Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

New Developments in Maintenance of Concrete and Brick Roads—
Mr. A. H. Hinkle, Superintendent of Maintenance, Indiana State Highway Commission.

Some Pointers for Public Officials Handling Highway Work—
Mr. Lawrence F. Orr, State Examiner, Indiana State Board of Accounts.

WEDNESDAY, JANUARY 21, 1925

Morning

Presiding, Mr. Don Heaton, President, Indiana County Surveyors' and County Engineers' Association.

Care of Bridge Floors—
Mr. Clyde Piper, Fayette County Highway Superintendent.

Discussion—
Mr. T. H. Ellis, Marion County Highway Superintendent.

Highway Bridge and Culvert Problems—
Mr. W. J. Titus, Bridge Engineer, Indiana State Highway Commission.

Discussion—
Professor E. L. Eriksen, in Charge of Structural Engineering Department, Purdue University.

Signs, Guard Rails and Railroad Crossings—
Mr. J. J. Griffith, ex-Marion County Engineer.

Discussion—
Mr. A. C. Mangus, St. Joseph County Highway Superintendent.

Afternoon

Presiding, Professor Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

A Program for County Road Maintenance—
Mr. Elmer Blue, Putnam County Highway Superintendent.

Discussion—
Mr. C. S. Loucks, Miami County Highway Superintendent.

New Developments in the Curing of Concrete Pavements—
Mr. H. F. Clemmer, Testing Engineer, Illinois State Highway Commission.

Some Characteristics of Concrete of Interest to Road Builders—
Professor R. B. Crepps, in Charge of Testing Materials Laboratory, Purdue University.

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THURSDAY, JANUARY 22, 1925

Morning

Presiding, Professor W. A. Knapp, Assistant Director of Engineering Extension Service, Purdue University.

Surveys and Plans for County Roads—
Mr. Don Heaton, Benton County Engineer.

Screened Gravel for Road Purposes—
Mr. Fred Hubbell, Steuben County Highway Superintendent.

Stone Roads of Monroe County—
Professor U. S. Hanna, Indiana University; Monroe County Engineer.

Maintenance by Team vs. Truck—
Mr. W. O. Jones, Wayne County Highway Superintendent.

Afternoon

Presiding, Professor G. E. Lommel, Associate Professor Topographical Engineering, Purdue University.

Contractors' Problems—
Mr. William Holland, Secretary, Indiana Association of Highway and Municipal Contractors.

Discussion—
Mr. S. S. Palma, Road Contractor, Lafayette, Ind.

New Developments in Construction Methods and Equipment—
Mr. C. Gray, Chief Engineer, Indiana State Highway Commission.

Road Law Procedure—
Mr. Ethan L. Arnold, Attorney, Elkhart, Ind.

FRIDAY, JANUARY 23, 1925

Morning

Presiding, Mr. A. A. Girton, President, City Street Commissioners' Association of the State of Indiana.

How Huntington Solved the Problem of Paving Its City Approaches—
Mr. W. F. Eberhart, Huntington County Highway Superintendent.

Re-Surfacing Badly Worn City Pavements—
Mr. R. H. Simpson, Chief Engineer, Department of Public Service, Division of Engineering and Construction, Columbus, Ohio.

Purdue Highway Extension Service During Summer of 1924—
Professor Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

Afternoon

Presiding, Professor Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

County Patrol Roads and Their Maintenance—
Mr. S. N. Johnson, Clinton County Highway Superintendent.

Use of Road Grader vs. Road Drag—

Grader—
Mr. S. B. Mylin, Wabash County Highway Superintendent.

Drag—
Mr. C. C. Hughes, Johnson County Highway Superintendent.

What Did You Do With Your Road Funds?
Mr. E. M. Murphy, Hendricks County Highway Superintendent.

Discussion—
Mr. William F. Mitchell, Perry County Highway Superintendent.

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MAINTENANCE OF MACADAM ROADS WITH BITUMINOUS MATERIALS

By V. C. LEE,
District Engineer, Indiana State Highway Commission.

The cost of maintenance of macadam roads by repeated applications of stone and by dragging has mounted to such enormous heights, due to the increased volume of traffic, that we must resort to some other form of maintenance whereby these costs can be reduced. Maintenance with bituminous materials is then a subject of extreme importance at this time, because by means of surface treating with bituminous materials we are able to salvage the old macadam foundation, product a surface which is maintained more easily and at less cost and provide a dustless surface for the traveling public and residents along the road. Surface treatment has been practiced for a number of years with very satisfactory results and since the idea is not new it will be my endeavor in this discussion to give you some of the methods of application, proportions of bituminous materials and covering as is practiced by the State Highway Commission.

Inasmuch as surface treatment can not provide drainage, a foundation or a base, only such macadam roads as already have these fundamentals should be considered for treatment. A great deal of money has been wasted on surface treatment because a careful study of the road construction was never made. Improper proportioning of materials, no consideration given to the amount of traffic the road must carry, and no provision for future maintenance are all important causes of failure in surface treatment.

Preliminary Work

Preparatory to surface treatment, we must first correct the surface of the old macadam road. An extreme crown should be eliminated by laying either a water-bound or traffic-bound macadam patch along the edges of the old macadam. This should be done either early in the season or a season in advance of the treatment. Next, such holes or ruts as may be found in the old road should be carefully patched, either with a water-bound macadam patch or with a bituminous concrete patch.

The introduction of bituminous cold patching materials has made the bituminous concrete patch both easy and economical to lay. Such a patch can be laid in a hole or depression from ¾ inch to 3½ inches in depth. Deeper holes should first be filled with No. 2 stone to within two inches of the surface and

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thoroughly tamped. The bituminous patch can then be laid on this foundation. The bituminous materials used in making this patch can be either tar cut back, asphalt cut back, or asphalt emulsion. The size of the stone used depends upon the depth of the hole and may range from ¾ inch to 2½ inches. Where the coarser stone are used a small portion of stone chips and clean coarse sand must be added to give a consistent mix. The amount to be added will have to be determined by experiment. Likewise, the exact proportion of bituminous materials used will depend on the quality and sizing of the stone and must be determined by experiment. Just enough bituminous material should be used to thoroughly coat the stone when it is properly mixed, so that no white spots will appear on the stone. Since the bituminous cold patch is used more often in the maintenance of bituminous macadam, I will discuss the manner of laying the patch later.

After the surface of the old road has been prepared for treatment, the next step of importance is the choice of bituminous material to use. The bituminous materials most commonly used for surface treatment are tars—hot, medium and cold; asphalt oils—hot, medium and cold, asphalt cut back and Trinidad cold oil. Which grade of these tars or asphalts to use, whether heavy, medium or light, will depend on the condition of the road to be treated, the amount of traffic and the future plans for maintenance.

Also the quantity of bituminous material to use, the amount of cleaning of the surface required and the amount and grade of stone required for covering will depend upon the nature of the surface to be treated, the amount of traffic and the kind of bituminous material used.

Before the application of the surface treatment one of the foremost and important essentials is the proper cleaning of the road surface. Where the heavier asphalts and tars are used, the surface should first be cleaned by the use of shovels, fiber brooms, and mechanical sweepers until the large stones comprising the macadam surface are completely exposed and clean, but not dislodged. The sweeping should be continued until the voids are exposed to a depth of about ½ inch, and the dust completely removed. When the medium asphalts and tars are used the sweeping need be carried only so far as to expose the voids in the surface. With the use of the light oils only the mud, dirt and excess loose dust or other foreign matter need to be removed from the surface, and but little if any sweeping will be required. Where the surface has been swept clean by auto traffic of all dust and screenings, so that the large stones in the surface are exposed, the cold oil treatment should not be used.

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Application of Bituminous Material

The application of the bituminous material should be made by a pressure distributor mounted on a truck. The material should be sprayed on with considerable pressure as this will remove any thin layer of dust on the stone and aid in the bonding of the bituminous material to the surface.

The amount of bituminous material applied will depend on the nature of the surface, the amount of traffic and grade of material used. For the first treatment on a water-bound or traffic-bound macadam surface the heavier asphalts may be applied from 1/3 to ½ gal. per sq. yd., the medium asphalts from 1/3 to ½ gal. per sq. yd., and the lighter oils from 1/3 to ½ gal. per sq. yd. The heavier tars may be applied from 0.4 to 0.5 gal. per sq. yd., and the cold tar from 1/3 to 0.6 gal. per sq. yd.

Where more than ¼ gal. per sq. yd. of bituminous material is used, it should be applied in two treatments. The second treatment can be applied as soon as the first treatment has been covered with just enough screenings to prevent the bituminous material from picking up or sticking to the wheels of vehicles and prevent the second treatment from flowing off while applying it.

For re-treatments, that is successive treatments applied each year, a much less quantity will be required. Usually 1/3 gal. per sq. yd. will give satisfactory results.

Covering Material

The amount and kind of covering material necessary will depend on the kind of bituminous material used and the condition of the road surface before the application. Ordinarily for the lighter oils no covering at all will be required for the first application, and this is also true when no more than 1/3 gal. per sq. yd. of cold tar is used. However, on succeeding applications of cold tar, a thin application of clean coarse sand or grit should be used. For the first treatment with the heavier asphalts and tars the amount of covering may range from 60 to 80 pounds of crushed stone per gallon of bituminous material used. The stone should be of a size passing a 1¼ inch circular opening and retained on a ½ inch screen. This size stone should constitute about 75 per cent of the covering and to this should be added about 25 per cent of chips or stone passing a ¾ inch circular opening and retained on a ¼ inch screen. This will give a better seal and make a uniform surface, for succeeding treatments of the heavier asphalts and tars, 30 to 60 pounds of stone chips per gallon of material used.

The use of the proper amount of covering is one of the very essential things to insure the success of bituminous surface

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treatments. However, owing to the variable conditions affecting the screenings required the best rule that can be made is to use just enough covering and no more than is required to prevent the bituminous material from being picked from the road by traffic. The surface should always look black after it has been ironed out by traffic. If it does not look black, but looks dry and light in color, it is an indication that too much covering has been used. There is not so much danger, however, in overloading with heavier asphalts as when lighter grades are used.

Screenings may be applied from piles of stone at the roadside by men with shovels or spread directly from dump trucks by opening the tail-gate just sufficiently to allow the stone to sprinkle uniformly on the surface. On sharp grades, the truck can not be used on account of slipping. The covering in all cases should be done in such a way as to insure an even distribution over the surface. Where the bituminous material is applied in two courses, only enough screenings should be applied after the first course to prevent picking by traffic, and keep the second course from flowing off when being applied. During the past year, the State has made use of the four-way steel drag and a No. 5 road maintainer for following up and smoothing the surface after the screenings have been applied. The drag serves the two-fold purpose of thoroughly coating the screenings with the bituminous material and dragging the excess screenings into the depressions, thus smoothing out the surface. Following up with the maintainer will eliminate any mark of ridges which might be left by the drag, thus giving a smooth uniform distribution over the entire surface.

A bituminous surface treatment should be repeated when it becomes necessary to replace the treatment previously applied. Usually succeeding treatments should be applied each year for two or three years after the first treatment has been made after which time re-treatment can be made two or more years apart.

Patching

Should holes or ruts occur before a re-treatment is applied, they may be eliminated by being brought up to the proper elevation by cold patching, which I have mentioned before, or by a bituminous paint patch where the depression is less than one inch in depth. In making the cold patch, the hole in the surface should not be enlarged or deepened, but must be thoroughly cleaned of all loose dust or foreign matter and swept clean. When asphalt and tar cut backs are used, the surface must be perfectly dry, but where asphalt emulsion is used, the hole may

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be flushed with water, but no excess water should be left standing in the hole. When clean, the surface to be patched must be painted with a bituminous material which may be the same as that used in making the patch. It is especially important that the edges of the hole be carefully painted but care must be taken not to use too much of the bituminous material in so doing.

The depression will then be filled with the bituminous mixture and thoroughly compacted in place by tamping or rolling. On this should be spread a light covering of coarse sand or grit and the tamping continued. The bituminous mixture may be prepared by either mixing on a platform or by use of a small concrete mixer. Where there is a quantity of patching to be done it is more economical to mix the material at a central mixing station and haul the mixture by truck to the roads that are to be repaired.

With the use of the asphalt and tar cut backs, the mixture should be placed in a pile and allowed to season sufficiently so that it will bind when the patch is made. This will require from 24 to 48 hours. Asphalt emulsion may be used as soon as mixed. It should not be allowed to stand for any great length of time, because it will become too hard to handle easily.

In making a paint patch when the depression is less than one inch in depth, the surface is first swept clean with a steel fiber broom followed by a house broom. When the surface is clean and dry, the depression may be painted with either medium or cold tar, hot asphalt or asphalt emulsion. The hot asphalt and medium tar will have to be heated before using. The cold tar can be used on an ordinary summer day without heating. Asphalt emulsion can be used at any ordinary air temperature. Stone chips will then be spread on the painted surface and thoroughly tamped until the bituminous material is forced into the chips a sufficient depth to bond them to the surface. The chips should then be covered with a thin coating of coarse sand and again tamped. Ordinarily No. 4 chips are the proper size to use, although it is well to have different sizes at hand to fit the depth of depression to be filled. In making a paint patch, great care must be taken not to use an excess of either the bituminous material or the chips, as this will later on produce bumps. It is better to build up the depression gradually to the proper elevation by more than one application than to use an excess on the first treatment.

During the last few years the State has salvaged by the patching process which I have just described and by subsequent surface treatments, many miles of roads which had received an initial surface treatment and on which there had been no further maintenance. Some of these roads were in such a condition

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when taken over that traffic could scarcely get over them, but today, after four years of maintenance they are carrying some of our heaviest traffic without showing any signs of wear or failure, and are becoming more and more like boulevards as time goes on.

BITUMINOUS MACADAM ROAD CONSTRUCTION

By A. O. HASTINGS,
District Engineer, Indiana State Highway Commission.

In selecting the type of pavement to be laid in a certain section of road careful study should be given to the amount and kind of traffic going over this road at present and also to the probable increase within the next few years. Careful study should be made of the condition of sub-soil and the old base.

If the present road has a good gravel or stone base that is holding up very well, a bituminous macadam top course is a very economical pavement to use. If it is a new grade there is a question whether some other types of pavement would not be as economical. One of the greatest economic reasons for laying a bituminous macadam pavement is the salvaging of the old base. A well compacted gravel or stone surface that has been hammered by heavy traffic for a period of years has considerable value and that value may be conserved by laying a bituminous macadam top course.

Grading

Let us consider first the grading. By use of a grader, wheel scoops, drag scoops or wagons, the berms, shoulders and ditches should be brought to the proper cross section and in conformity to the base grade taking care of the drainage as necessary. Unlike many other types, the shoulders on a bituminous macadam road should be built prior to the laying of the pavement. Many bituminous macadam roads have been built with but little berm. Much better results could have been secured had there been a good berm built before the pavement.

The cross section for an 18 foot pavement includes a 2 inch crown in the pavement proper with berms 5 to 6 feet wide sloping ½ inch per foot and with a flat slope of approximately 4 to 1 into the ditch. The old base should be reinforced and levelled up with a water-bound macadam course or at least patched with water-bound patches so that the foundation grade will conform very closely to the finished crown and grade and to sufficient depth to hold up the loads which it will have to carry. Much care should be used in leveling up the old base

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as much better results will be secured in the finished surface if the top course is the same thickness at all places. Specifications for laying a water-bound course to level up old base should be about as rigid as if the road was to be left as a water bound surface.

Suggested Specifications for Water-Bound Macadam Course

This course shall consist of a one course water-bound limestone, slag or crushed boulders, of a depth indicated on the plans or the estimate (this depth should be chosen after careful study of the old base), constructed in accordance with these specifications on the base course which shall be trued up where necessary with water-bound macadam patches, to a uniform grade and crown before the top course is placed thereon.

The coarse aggregate for this course shall consist of No. 1 (3½" to 2½") or No. 2 (2½" to 1½") size specified according to thickness of patch or course.

(A) Crushed stone shall consist of angular fragments of tough, durable crushed lime stone, trap rock, or boulders, having a French co-efficient of wear of not less than seven. It shall be free from thin and elongated pieces. If it is produced from crushed boulders, not more than ¼ the surface area shall consist of the original smooth surface of the boulder.

(B) Slag—The screenings used in filling this course shall consist of crushed limestone or slag meeting the above specifications except as to size. No. 7 (½" to 0) size screenings shall be used, if of slag or limestone with a French co-efficient of wear of more than nine. No. 5 (¾" to 0) screenings shall be used if of limestone with a French co-efficient of wear of nine or less.

No coarse aggregate shall be placed until the screenings for filling same have been neatly stored in piles along the side of the highway.

The coarse aggregate shall be spread on the base to such thickness as will produce the complete depth called for. Side forms of the proper size should be used to fix the depth of loose material and assist in spreading the same to a uniform surface. In spreading care must be taken to preserve the grade and crown, also to prevent a wavy irregular surface. After the stone is spread on the base it should be harrowed to aid in producing a uniform and even surface. Any thin, flat, elongated or oversized stone that appear on the surface at any time during the progress of the work should be broken up or removed. Special care should be taken to have a uniform material in the surface in order to secure a smooth and uniform finished base.

All patches or areas of fine or under-sized materials appearing in this course should be removed and replaced with suitable material before final filling and water-binding.

Rolling: The coarse aggregate should be rolled with a self-propelled three wheel roller weighing not less than ten tons. The rolling should begin with the outside drive wheel covering at least equal parts of metal and shoulder, and if the shoulder is sufficiently strong and uniformly built it is well to have even more of the roller wheel out on the shoulder the first trip. The roller should be run forward and backward along the edge of the metal until the shoulder and the metal are firmly bound together. The rolling should then progress gradually towards the center of the road laping about ⅔ width of the rear roller wheel until the entire course has been thoroughly keyed and the interstices of the metal reduced to a minimum and all settlement in the stone has ceased. Should any low

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places develop in the surface during the rolling, the stone shall be loosened and enough coarse aggregate added to make a smooth and uniform finished surface.

After the dry rolling has been completed as described above, screening should be applied gradually over the surface during the finishing process of dry rolling in such an amount as will completely fill the interstices. The screenings should not be dumped on the surface of the stone but should be cast thinly with spreading motion of the shovel from piles at the road side. The rolling should continue while the screenings are being spread so that the jarring effect of the roller will cause them to settle to the bottom. Care should be exercised not to apply the screenings too fast and choke the stone but the large stone should be kept in sight at all times. Continue to add screenings until all voids are filled, **the direct bearing of the roller still being on the coarse aggregate.**

Immediately after the voids of a section of the macadam have been filled with screenings as above described, the macadam should be sprinkled until saturated, the sprinkler being followed by the roller. More screenings should be added if necessary. The sprinkling, sweeping and rolling should continue until a grout has been formed of the screenings and water that will fill all of the voids and form a wave of grout before the wheels of the roller. The macadam should be kept wet at least twenty-four hours before the final rolling, and it should be puddled as many times as it is necessary to procure satisfactory results. When a section has been thoroughly filled and grouted as described above such section should be allowed to dry out after which it is ready for the application of the bituminous macadam course.

The approximate cost of this course varies according to the amount of reinforcement necessary on the old base, but striking an average from the cost of State jobs coming under my supervision, will average approximately 50 cents per square yard or approximately $5,200.00 per mile, 18 feet wide. After the base has been properly reinforced and leveled up with the water-bound macadam we shall proceed with the laying of the top course of bituminous macadam. This course should be about three inches in thickness when thoroughly compacted.

The Bituminous Macadam Course

At this time the berms should be carefully graded and any irregularities leveled off so that when rolling is started on the top course with half of the roller wheel running out on the berm, the earth forming the berm will compact to a true grade, just level with the grade of the edge of the stone in the bituminous macadam course. Should there be high and low places in the berms the irregularities will follow the rolling as it progresses towards the center of the road and a wavy irregular surface will be produced.

Berm boards should be used in spreading the coarse aggregate. Very handy berm boards for a three inch compacted course are 2"x4" timbers set on edge, lined and leveled with the proposed line and grade. The coarse aggregate being dumped and spread to crown and grade, and checked up by use

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of a crown board resting on the berm boards. The coarse aggregate may be dumped on the surface and spread by hand or a rough spread made by use of spreader boxes. Very careful spreading of the coarse aggregate is necessary to produce a smooth surface.

When the coarse stone has been carefully spread it should be rolled in the same manner as described in water-binding beginning with half the roller wheel on the berm and progressing towards the center of the road until the coarse stone is thoroughly keyed but not rolled enough to crush much of the stone.

The coarse aggregate should consist of crushed stone or slag all passing a 3½ inch opening when the per cent of wear is less than 4½ and a 4 inch circular opening when the per cent of wear is 4½ or more. Not over 25 per cent should pass a two inch opening; 6 per cent a 1½ inch opening, and 2 per cent a 1 inch opening.

When the coarse aggregate has been properly keyed it is ready for the application of the first coat of bituminous material meeting state highway specifications for Tar TP-6 or Asphalt A-2. The bituminous material should be applied to the aggregate when it is dry, when the temperature is above 45 degrees F. and when the lowest temperature within the proceeding eight hours has been above 32 degrees F. The coarse aggregate should be disturbed as little as possible by the application of the bituminous material. The bituminous material should be uniformly applied at the rate of 1¾ gallons per square yard and at a pressure of not less than 25 pounds per square inch by means of an approved pressure distributor. The distributor should be a self-propelled distributor with a manifold having a horizontal shift of not less than ten inches and should be equipped with wide tires to disturb the stone as little as possible. Hand pouring pots or nozzles should not be used except where special conditions would make it impracticable to use the distributor. The bituminous material should be heated by suitable appliance so designed as to admit of even heating of the entire mass with an efficient positive control of the heat at all times. Care should be taken so that the bituminous material is not heated beyond the highest permitted temperature specified, either before or during the application.

The coarse covering (key stone) should have been placed in neat piles along the berm prior to the spreading of the coarse stone. It should meet the specifications required for coarse aggregate except as to size. The coarse covering should all pass a 1½ inch circular opening with not over 5 per cent retained on a 1¼ inch screen, 70 to 100 per cent should be retained on a ¾ inch screen with not over 15 per cent passing a ½ inch opening.

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Immediately after the bituminous material is applied there should be evenly spread over the surface just sufficient coarse covering material to prevent the bituminous material from sticking to the wheels of the roller (approximately 1 cubic yard to 125 square yards of surface). The road should then be rolled thoroughly before the bituminous material hardens enough to prevent the covering material from being readily incorporated with it. Should it be cool weather the rolling must progress rapidly. If it is extremely warm, it is sometimes necessary to wait and allow the bituminous material to cool some before rolling. As the rolling progresses additional covering should be added and broomed into the voids, care being taken not to put on an excess of covering at this time. The rolling should continue until a solid compact and smooth surface results conforming to the cross section on the plans. Should any humps or depressions develop during this rolling, the coarse aggregate should be loosened and additional stone and bituminous material added so that when rolled it will produce a smooth surface.

When sufficient rolling has been done and the voids fairly well filled with covering stone the first seal coat of heavy bituminous material should be applied consisting of about ¾ gallon per square yard of surface. Then the fine covering is spread evenly over the bituminous material in a thin layer just sufficient to keep the bituminous material from sticking to the roller wheels and the road should be **thoroughly** rolled. At this point in the construction of a bituminous macadam road I do not think it would be possible to roll too much. Fine covering should be broomed into the voids until the voids are well filled. At this time the second seal or surface treatment should be applied consisting of a lighter bituminous material (Indiana state highway specifications for asphalt OH-2 or Tar TM) at the rate of about 3/10 gallon per square yard of surface. After applying the final seal coat of bituminous material, fine covering should be applied and if asphalt is used it should be rolled. If Tar TM is used the surface should be dragged as explained for surface treatment of Tar TM.

By conserving the old base a good pavement may be laid as described above at a very reasonable cost.

The following are a few points to be watched carefully in the above described method that will materially help in securing better results:

1. See to it that the berm compacts smooth and true to grade as the rolling begins. After the first application of bituminous material do not apply too much coarse covering but apply just enough to pass the roller without the bituminous material sticking to the wheels.

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2. Roll until the coarse stone is thoroughly compacted, and feed in coarse covering as needed, do not choke it.

3. After second application of bituminous material apply only enough fine covering to get the roller over it without picking up, and roll thoroughly before additional fine covering is added. Fill the voids, but do not choke it.

4. At all times during the process of construction of both the water-bound and the bituminous macadam top courses, the coarse stone should be visible on the surface of the road.

5. Keep the cover stone spread uniformly. If for any reason it is applied alternately thick and thin, it should be thoroughly broomed before rolling. A bunch of chips will cause a depression in the road for when the roller hits a pile of chips the coarse stone is mashed down and when traffic comes on the road the pad of fine stone is brushed off and a dip in the surface results.

6. Emphasis should be given to the amount of rolling. Too much rolling can not be done after the first seal coat is applied, and also after the surface treatment, where asphalt is used. Some roads have been built without enough rolling at the proper time and costly maintenance follows.

Costs

As to the cost of constructing an 18 foot bituminous macadam pavement, three inches thick when compacted, I will quote from prices paid by the State for pavements laid in my district. Between Chester and Fountain City in Wayne County the cost was 90 cents per square yard. Pavement laid on the National Road east and west of Richmond, using some additional stone to level up the old base which was already a surface treated macadam, cost $1.07 per square yard. Pavement laid between Muncie and Selma about 85 cents per square yard.

The above will average from $9,000.00 to $11,000.00 per mile for an 18 foot surface varying mainly as to cost of the aggregate used. Adding the expense of reinforcing the old base with water bound macadam to the cost of laying a bituminous macadam top course gives a total cost of about $15,000.00 per mile of completed surface.

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CARE OF BRIDGE FLOORS

By CLYDE PIPER,
Fayette County Highway Superintendent.

Fayette County's steel bridges are of the various kinds that are general over the State, with the usual floor construction, namely, plank, creosoted wood block, and concrete, all of which have their limitations and objections. These bridges are today carrying loads that the designed and builder never dreamed would be found on our highways. Traversed as Fayette County is by the Whitewater River and its tributaries, there is hardly a main or secondary road without a steel bridge of some size.

We have tried to conserve our floors to get the greatest possible use from them. Originally the floors were nearly all 3 inch plank laid crosswise. This plan under present traffic, subjects the bridge to considerable vibration and the floor plank to a heavy impact from the wheels, which results in broken planks.

We have floored the bridges with a length-wise flooring, 10 to 12 feet wide, with planks 2 inches thick. This strengthens the floor, eliminates vibration, noise and broken planks. These bridges were floored originally with native oak, which is practically out of local market. At present many of these have the second top floor on them, lengthening the life of the first floor several years.

The creosoted wood block floor is susceptible to water and then heaving follows. We have a block floor that has been in use for many years. My predecessor had taken this floor up and relaid it several years ago. Some of the blocks were deteriorating and were odd shape from the pressure of heaving until we were unable to hold them down with any treatment we had used. We used a concrete mixer and the cold mix asphalt with washed pebbles and sand, running them through the mixer until the pebbles were thoroughly coated. This mix was spread on the floor 1½ inches in thickness, leveled down smooth and covered with sand to take care of any surplus asphalt in the mix. This job so far has been very satisfactory and did not add much dead weight to the floor. We have had very good success with other block floors by treating them the second year after they were laid with the used oil from our motor trucks. We sweep the floor with fiber push brooms first, then follow with a heavy stable broom, removing all dust and dirt possible, scraping any substance that adheres to blocks. Then follow with sprinkling

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cans and fiber brooms, brushing the oil until the floor is thoroughly covered.

We have also used the cold mix asphalt on block floors. All dust and dirt must be removed, scraping any that adheres to the floor, thorough cleaning being necessary to insure a successful job. When asphalt strikes dust it will not adhere at all, while the oil will penetrate a little dust. The floor being clean the asphalt is poured on and brushed until the floor is fully coated. Then dry sand is sprinkled over the floor. The sand-coat follows closely after the brushing. We have had very satisfactory results with this treatment. Either of these treatments gives a covering for the floor that is a preservative and is also water-proof.

Concrete floors should be watched closely for checks or cracks. Should any appear they should be taken care of immediately. Any depressions appearing should be filled with tar or asphalt, bringing them up to a level with the floor.

Several of our old plank floors have been replaced with a creosoted oak made up of 2x4's set on edge and fastened together, with 3 angle bar tie rods, into slabs one foot in width. This type of floor makes a self cleaning surface and is free from swelling or bulging. Some we have laid were bolted to the channel irons through the end of each plank or slab. After laying some in this way we changed and laid a 3x4 creosoted timber on each end, using only three bolts to the piece which speeds up the laying of the floor and also cuts the cost. These floors should be covered with asphalt, preferably the cold mix, brushed in with broom and sanded. They are laid without skilled labor, can be laid rapidly, and require closing the bridge for only a short time. They carry little dead weight in proportion to their strength.

There is on the market rolled iron plate made in different widths to be placed on the old wooden floor at the traffic lanes. It eliminates vibration, wear on the floor and also serves as a traffic guide. It presents a non-skid surface and makes a nice driveway.

A bridge floor to give all the service possible should be level with the road or approach and should be kept smooth to eliminate all vibration possible.

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NEW DEVELOPMENTS IN THE CURING OF CONCRETE PAVEMENTS

By H. F. CLEMMER,
Engineer of Materials, Illinois Division of Highways.

Experience and investigation in the past few years have developed many refinements and improved methods in the construction of concrete pavements. Increased traffic on the highways has demanded that every effort be made to improve conditions affecting the convenience as well as the safety and comfort of the travelling public.

In accordance with this policy attention has been given to such matters of design and construction as that of obtaining smoothness of surface, increasing the radius of curves, widening of curves and the enforcement of regulations with regard to advertising signs on highways, elimination of grade crossings, and extension of vision at railroad crossings and highway intersections.

State Highway Departments, Technical Societies and Engineering Universities have made studies and investigations on problems affecting the quality of pavements such as design of mix, rules of proportioning, suitability of various types of sands, stone, and cement, durability of concrete, stress phenomena, admixtures, accelerators, and methods of curing.

Possibly one of the most interesting problems at the present time is the development of new processes in curing concrete pavements. Old blanket methods of curing by dirt, water and straw are reliable if properly carried out. However, an increasingly important factor in daily business and personal conduct is that of time, and as a result it has been asked, "Can we speed up construction" and "Can we cut down the curing period on concrete pavement?"

Early in the history of Portland cement it was known that certain chemicals accelerated the set of cement. Calcium chloride and allied compounds were found to be the best for this purpose. Reliable tests have been made which indicate that the time required for proper curing may be reduced 25 to 50 per cent, representing to the public an enormous saving in travel cost as well as convenience. As given in a table compiled recently by Prof. T. R. Agg, of Iowa State College, the cost of operating a passenger automobile over ordinary earth roads is 12.6 cents per ton-mile as compared with a cost of 9.3 cents over a good concrete pavement, making the difference in cost of operation 3.3

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cents per ton-mile, or an average of 4.1 cents per care-mile considering the average weight per car to be 2,500 pounds. In the construction of 1,000 miles of pavement in one year necessitating 1,500 miles of detour with the average daily traffic of 500 cars, there is a saving of $900,000 to the motorists, if the construction period is cut down 15 days. This astounding sum, as well as many of the worries incident to detouring, is saved to the motorist and the cost of detour maintenance is saved to the State, if the time required for the proper curing of concrete can be reduced from 30 to 15 days. A further advantage in this method of curing is realized in cases where water for curing is not readily available and, therefore, must be piped or hauled at great cost, where dirt in sufficient quantities is likewise costly.

The surface application of calcium chloride may be properly called a recent development in curing of concrete pavements. Its importance is reflected in the fact that several state highway departments have, during the past two years, adopted as alternative the curing of pavements by calcium chloride and others are investigating and considering the method. Nearly three years ago as a result of tests made up to that date instructions were issued to engineers of the Illinois Division of Highways covering the use of calcium chloride as a curing agent applied dry to the surface of the concrete and used in solution as an admixture. The instructions issued were as follows:

"Use on the Surface of Pavements for Curing.—Calcium chloride may be used in connection with curing of pavements, taking the place of the usual curing with earth and water, or the curing with water by what is known as the 'pounding method.' Two and one-half (2½) pounds of the flaked or granular material (the flaked is preferred as it is more easily distributed and less easily removed by wind or rain) shall be applied to each square yard of pavement and it shall be distributed uniformly over the surface of the finished pavement by means of a mechanical drilling device or by the use of shovels and long handled brooms. The material shall not be spread upon the pavement until the latter has thoroughly set, ordinarily from six to eight hours after laying the pavement. Care shall be taken that the material is uniformly spread and if, in the opinion of the engineer, a uniform distribution is not obtained from the shovels, a thorough brooming shall be required. All lumps shall be broken up and uniformly distributed over the surface.

Calcium chloride shall not be applied during rains and experiments have definitely determined that, if a rain follows the placing of the calcium chloride after a period of two or three hours there will have been enough absorption of the calcium

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chloride by the new pavement preceding the rain that there will not be required additional applications of the material.

Incorporating in the Mix to Hasten the Set.—The Department will permit the use of calcium chloride in the concrete mix for pavement construction during cold weather. When used, the solid, granulated, flaked or powdered materials shall be thoroughly dissolved in water. It is recommended that the proper amount of calcium chloride solution should enter the mixer drum just before the water is added to mix the aggregates, or the solution may be added direct to the stone or sand when in the skip, but in either case the method of handling this solution shall be approved by the engineer.

When used in the pavement work, not more than **two per cent (2%) by weight of the cement shall be used.**

Calcium chloride should not be used in a pavement that crosses an electric railroad but its use should be discontinued approximately one-quarter of a mile from the electric railroad crossing. There is no objection to using the material when the highway parallels an electric line.

It is not definitely known at what temperature concrete will freeze when the two per cent of calcium chloride is mixed with the concrete and it will, therefore, be necessary to arrange to cover the pavement with loose straw or earth as soon as it has taken sufficient set to prevent marring of the surface. In other words, calcium chloride hastens the setting of the concrete, but is in no sense a protective. It makes possible an earlier application of a straw or earth covering.

Due to its action on reinforcing steel, calcium chloride shall not be used in bridge or culvert construction; therefore, the usual precautions should be taken when placing concrete in culverts and bridges during temperatures around the freezing point."

The above instructions cover in general those issued by highway departments of the various other state and municipalities permitting the use of calcium chloride.

The investigations that have determined the action and suitability of various materials as curing agents have been conducted by several laboratories, including the U. S. Bureau of Public Roads, the Structural Materials Laboratory of the Lewis Institute, and the Illinois Highway Laboratory. The results of these experiments are available in publications and although a detailed discussion would be somewhat cumbersome pertinent conclusions may be quoted.

1. "In the use of calcium chloride no advantage was gained for percentage of the commercial product greater than 2 or 3 per cent of the weight of cement (Chlorine content 1

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to 1½ per cent). This amount when used in mixes of about 1:5 and in consistencies suitable for building construction, showed an increase in compressive strength of from 100 to 200 pounds per square inch, which increase was practically constant at ages of 2 days to 3 years. For richer mixes and drier consistencies the strength increase was greater and for leaner mixes and wetter concretes it was less." (Bulletin 13, by Duff A. Abrams, Structural Materials Research Laboratory, Lewis Institute.)

2. "Concrete cured with a surface application of calcium chloride of suitable intensity will attain approximately the same strength in 14 days as concrete cured by wet dirt or other similar methods in 28 days." (Can We Cut Down the Curing Period for Concrete Roads? by H. F. Clemmer, A. R. B. A. Convention, 1924.)

Investigations in curing of concrete were begun by the Illinois Highway Laboratory about three years ago, shortly after construction of the Bates Experimental Road. Tests were made to determine the effects of its use, in the dry form, as a surface curing agent, and in solution as an admixture. A review of the results is included in the Proceedings of the American Society for Testing Materials (1923) under the title, "An Investigation in the Use of Calcium Chloride as a Curing Agent for Concrete," and a later paper entitled, "Can We Cut Down the Curing Period for Concrete Roads," presented at the 1924 convention of the American Road Builders' Association at Chicago.

The investigations were conducted in several series, a general review of which follows:

Over 2,000 specimens were used, including 500 beams 8"x 12"x30", 100 cylinders made to serve as a check on quality of the concrete, 1,000 cylinders and tensile briquettes of 1:3 mortar and neat mixtures, and in addition slabs of various sizes for determination of wear and other surface phenomena. A volumetric mix of 1:2:3½ standard in Illinois for highway work, was used and all stone, sand and cement were tested in accordance with state specifications.

External Treatment

Since the primary interest was in strengths obtained at 14 and 28 days the greater number of specimens were tested at these ages. Tests were also made at 60-day, 90-day, 6 month, 1 year and 2 year periods.

Series 1.—Series 1 included 260 specimens, 100 poured in forms made by excavating to the desired depth in the ground and placing wooden sides, 60 poured in oiled wood forms and 100 poured in concrete forms. Canvas protection against weather

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conditions was provided. The purpose of using the concrete forms as shown was to duplicate as nearly as possible pavement conditions. Specimens in this series were given the following treatments: 2 inch dirt wet, 3 days; 2 inch dirt wet, 7 days; 2 inch dirt wet, 14 days; 1 pound per square yard calcium chloride, 1 pound per square yard calcium chloride with 1 inch dirt, 3 pounds per square yard calcium chloride, 3 pounds per square yard calcium chloride with 1 inch dirt, ½ to 2/3 gallon per square yard asphalt.

Series 2.—The specimens in this series were poured both in oiled wood forms and in concrete forms. The effect of an oiled sub-grade, as well as the use of magnesium calcium chloride and sodium silicate as curing agents was investigated in this series.

The specimens in this series were given the following treatments: 3 pounds per square yard calcium chloride after 10 hours, 3 pounds per square yard calcium chloride after 24 hours, 3 pounds per square yard calcium chloride after 10 hours washed off 12 hours later, 3 pounds per square yard magnesium calcium chloride after 10 hours, 3 pounds per square yard magnesium calcium chloride after 24 hours, 1/5 normal solution of sodium silicate after 10 hours, 1/5 normal solution of sodium silicate after 24 hours, 2 inch dirt wet, 7 days; 2 inch dirt wet, 14 days; 2 inch dirt wet 7 days (Sub-grade oiled). These specimens were tested at the ages of 14 and 28 days.

Series 3.—In this series specimens were cured with surface treatments of various forms of calcium chloride in order to compare the effect of using dry calcium chloride with that of using solutions of the chemical.

Results

These results may be interpreted from several angles but considering the subject of this paper, the most valuable and significant comparisons to be drawn are those that demonstrate the ability of calcium chloride curing to secure as great a strength in 14 days as is obtained by the use of wet earth in 28 days.

For the purpose of a practical interpretation of the results of Series 1, Fig. 1 has been included, showing the 28-day transverse strength of the specimens in per cent, using as 100 per cent, the transverse strength obtained from the specimens cured with earth wet 14 days. This comparison is especially significant since wetted earth curing is universally considered as satisfactory.

As a second interpretation of the Series 1 tests, Fig. 2 shows a chart illustrating the fact that greater transverse strength is obtained by the use of calcium chloride in 14 days than by the other methods in 28 days.

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Results of experiments confined to the comparison of the effects of surface application of dry calcium chloride as compared with the external use of solutions of the chemical show the dry chemical to be far superior. Specimens cured with dry chemical applied externally had moduli of rupture averaging approximately 760 while those treated externally with 60 per cent solutions averaged approximately 590, and 30 per cent solutions

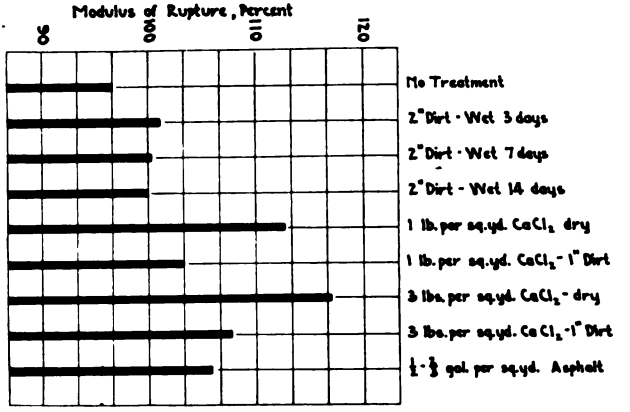

Modulus of Rupture, Percent
90
100
110
120
No Treatment
2" Dirt - Wet 3 days
2" Dirt - Wet 7 days
2" Dirt - Wet 14 days
1 lb. per sq.yd. CaCl2 dry
1 lb. per sq.yd. CaCl2 - 1" Dirt
3 lbs. per sq.yd. CaCl2 - dry
3 lbs. per sq.yd. CaCl2 - 1" Dirt
½ - ¾ gal. per sq.yd. Asphalt

Fig. 1. Transverse strength of specimens at 28 days.

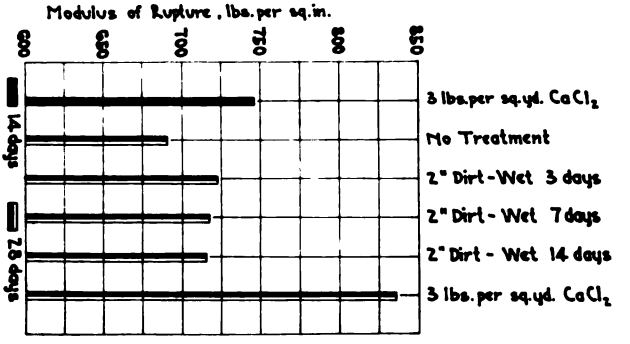


Fig. 2. Transverse strength at 14 and 28 days.

averaged approximately 545. It was thought at the time that if the method was found satisfactory the application of a concentrated solution of calcium chloride would be somewhat more convenient and uniform than treatment with the dry material.

Properties of Calcium Chloride Applied Externally:

In order to study the hygroscopic properties of calcium chloride and the extent of moisture attraction, mortar specimens of uniform weight were made and treated with varying quantities of calcium chloride, including a series of specimens having

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no treatment. After being treated, these samples were weighed at intervals of one hour and the loss or gain in weight calculated.

A weight greater than the original was observed on all treated specimens for a period of as high as 45 hours, the untreated specimens, however, exhibiting an immediate loss. The fact that this action is proportional to the strength of the treatment is also apparent and leads to the theory that the hygroscopic chemical freshly applied attracts moisture from the air in proportion to the amount used until the absorbed moisture is in equilibrium with that of the air, after which by absorption into the concrete and loss by mechanical means, the amount of chemical, and necessarily water, gradually decrease. The property of calcium chloride of maintaining the moisture content of the concrete at a higher percentage during the first 48 hours, leads to the belief that the chemical serves to prevent the formation of transverse cracks caused by shrinkage. General observation indicates that fewer transverse cracks occur in concrete pavements cured with calcium chloride than in those cured by ponding or wetted earth. This is being definitely investigated in Illinois at the present time.

Calcium Chloride on Concrete Surfaces:

Laboratory investigation was made to determine the effect of excessive amounts of calcium chloride on concrete surfaces. To illustrate the various effects, tensile briquettes of 1:3 mortar were made and treated. Specimens treated with a surface application of dry calcium chloride such as would be equivalent to 10 pounds per square yard of surface indicated slight puffing due to this excessive use of the chemical. It was noted that the tensile strength of these briquettes at the age of 28 days was not affected by the excessive amount of calcium chloride. In practice, however, contractors are cautioned against the use of excessive quantities and are instructed to break all lumps and spread the material evenly on the surface.

Wear of Surface:

To gain an insight into the wearing value of the treated surface of concrete pavements, several slabs have been cast and tested at various ages in a machine designed especially to approximate the wear of a concrete pavement. A wear machine is used in which the specimen is clamped horizontally to the frame of the apparatus and wear effected by the abrasion of two metal weights with the aid of a constant flow of standard abrasive material. The depth of wear is determined by Ames dials, using reference points on the specimen.

The treated surface using 2½ pounds per square yard of calcium chloride, shows an almost imperceptible wear of 0.024

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inch, while the untreated surface shows a distinct depth of abrasion of 0.20 inch under the same number of revolutions of the apparatus.

The ease with which calcium chloride in proper condition may be spread is apparent, very little labor being required for the operation. The method of application has been left to the contractor or resident engineer and there have been developed as a result several implements and methods by which the material may be applied. One requirement of the department, however, is that a uniform application be made.

The results obtained so far by no means limit the extent to which further investigation may be continued or the problems to which chemical curing may be applied. Several laboratories, as well as the Illinois Highway Laboratory, are conducting work on the curing of concrete which will no doubt prove of great value in the future. Experiments have progressed to a point, however, where the question of cutting down the curing period for concrete pavement can be definitely answered.

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WHAT DID YOU DO WITH YOUR ROAD FUNDS?

By E. M. MURPHY,
Hendricks County Highway Superintendent.

Ever since it was established, the office of the County Highway Superintendent has been considered a joke by a class of people that do not know the facts with reference to road maintenance. Only two years ago at our last legislature there were fourteen bills introduced in the House to modify in some way or other, the Highway Superintendent's Office, or to absolutely abolish it. The amount and cost of material and equipment used makes it the biggest job from an administrative standpoint of any in the county.

I have organized our county into sixteen districts with an assistant superintendent over each district. The road funds for the work of maintaining the roads of the county are apportioned with due regard to the topography, condition, character and volume of traffic, availability of good road repair materials, drainage, etc.

During 1924 we graded twenty-five miles of road, dragged and rolled several miles of rock road to a smooth surface, and scarified and graded a number of streets in small towns. Some township roads were graded, the county furnishing the road roller and grader and the trustee paying the operating expenses. During the last three years we have graded 135 miles of road, using a large grader with a steam roller, scarifying the road and moving the gravel to the center to permit building of the berm and side ditches. After leveling and rolling the berm we moved the material back to the edge of the berm and rolled again making the travelled way of the road perfectly smooth, with just sufficient crown for drainage.

We have several towns in our county with a population running from six hundred to one thousand inhabitants, the streets of which were a part of roads constructed under the Three Mile Road Law. These had been maintained by adding new material until the center of the streets were entirely too high. To make them safe for travel and give parking space along the side, it was necessary to scarify the streets, remove the excess dirt, regrade, level, roll down to a smooth surface, and then resurface with new material. The county paid for the new material and furnished the trucks and drivers. The Town Board furnished the help to shovel the material into the trucks and also hauled away the excess scarified material in the streets. We have

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treated the streets in this manner in eight such towns in our county in the last three years.

We have also furnished rock for part of the roads in the county in the amount of 7,000 tons; also washed and screened gravel shipped into the county in the amount of 5,800 tons; washed and screened gravel from our home plant in the amount of 3,400 tons; creek, bank and dipped gravel in the amount of 33,781 yards, graveling in all a distance of 125 miles, besides repairing other roads.

We have seven trucks, two of these trucks we rebuilt last year making them as good as new. We have a mechanic in our employ that keeps our trucks in repair at all times, and also drives our road roller when rolling and grading the roads, and is paid out of the road funds at 50 cents per hour.

We have six big wooden drags that we have built, and always keep material on hands for building and repairing drags.

I have divided my road funds into the following items of road expense:

Day Labor, 25 cents to 30 cents per hour	$ 4,195.15
Team and drivers, 50 cents to 60 cents per hour	32,142.83
Of which $5,742.97 was paid out for dragging, grading and spreading gravel in the different districts.	
Total cost work done with county trucks	9,553.89
Most of this item was for hauling new material, such as stone and gravel, mostly on long distant hauls.	
New material—gravel and stone	28,667.96
Tools and machinery	3,842.68
About $1,000.00 was spent for rebuilding two old Indiana trucks.	
Drags and slip scrapers	319.30
Sewer pipe	311.92
Miscellaneous items of expense	2,801.58
Lumber for drags, drain tile, hardware, tarvia and cold patch.	
Superintendent's salary	1,380.00
Plus mileage for looking after road work	711.50
Asst. Superintendents' salaries	4,145.88
Total	$88,072.69

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WHAT DID YOU DO WITH YOUR ROAD FUNDS?

Discussion by WILLIAM MITCHELL,
Perry County Highway Superintendent.

In the maintenance of Perry County highways, instead of using assistant highway superintendents under a specific salary, I have divided our roads into sections of about seven miles each, and placed these in care of a patrolman who lives in the vicinity of his patrol section. I often procure these patrolmen for $2.00 to $2.50 per day, thereby saving the county the difference between these figures and $3.00 per day, the fixed salary of an assistant superintendent.

Our main work has entailed the reconstruction of several newly built roads as well as some of the older ones. This has included the lengthening of culverts, widening the road bed, and resurfacing with river gravel, also the easing of some of our dangerous curves and moving stumps and large stones from side ditches and drains.

Resurfacing can not be done at a very rapid rate with our present maintenance funds in view of the fact that this work costs us about $800.00 per mile. This is based on an average five mile haul and about 250 cubic yards of gravel per mile.

It is true that we have some roads that have not been properly constructed, and I presume that many other counties are confronted with the same conditions, but these roads are a part of our system and have to be maintained along with the better built roads. We have a little more than 82 miles, mostly inferior type roads, and the maintenance proposition which confronts the taxpayers of our county is one of deep concern. As I see it, either the legislature will have to relieve our poorer counties by giving us more gas tax, or a still heavier burden must be placed on the taxpayers in order that our roads may be properly maintained.

You can see that with only ten million dollars assessed value of property in our county what a burden has been placed on our people to build 82 miles of improved road that we have, and the maintenance problem is a still greater burden than the first cost.

The following table shows how our maintenance funds were used in 1924:

Taxable property		$10,000,000.00
Gravel road repair rate		.20
Money derived from taxes	$19,462.20	
Gas tax from state	3,155.97	
Total money available		$22,618.17

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County mileage	82.09 miles
Miles of road repaired	70.00 miles
Expended on roads (approximately)	$17,000.00
New machinery purchased and other items	1,500.00
Balance, December 22, 1924	4,000.00

Classification:

Labor	$3,300.00
Team and truck	6,300.00
Materials and supplies	5,100.00
Superintendent's salary	1,096.00
Superintendent's expense	167.70

HOW HUNTINGTON SOLVED THE PROBLEM OF PAVING ITS CITY APPROACHES

By W. F. EBERHART,
Huntington County Highway Superintendent.

The improvement of the approaches to the City of Huntington has been the subject of discussion for a number of years.

In 1922 a petition was filed to improve one of the approaches to the city under the County Unit Road Law. The figures in Table I were compiled and attention directed to the fact that the wealthiest township (Huntington) in the county had only spent about an equal amount with the other townships for roads. Expenditures under the Three Mile Road Law were used in the table for comparison.

About 225 miles of road had been built by taxing costs against farms one and one-half to two miles on each side of the roads improved. However, it was thought best to limit comparisons to more recent construction.

The attention of civic and business organizations such as Kiwanis, Rotary and Exchange clubs and the Chamber of Commerce was directed to the relative amount of road work done by the various taxing units of the county. Their co-operation was secured in making out an equitable solution of the problem of city approaches.

By common consent it was agreed that Huntington Township should bear the expense of hard surfacing the main approaches to the city.

Petitions were circulated similtaneously for the improvement and each person was asked to sign all of the petitions. Between six and seven hundred names were signed on each petition. A remonstrance under such conditions seemed practically

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useless. In spite of the fact that we were almost unanimous that the things should be done, difficulties arose when the type of pavement was to be determined. To date, we have plans for concrete, Kentucky rock asphalt on concrete, Kentucky rock asphalt on macadam, sheet asphalt on concrete, and sheet asphalt on macadam.

We have received assistance from the Engineering Extension Service of Purdue University and the State Highway Commission and present indications are that our plans will be carried out successfully in the near future.

TABLE I.—HUNTINGTON COUNTY ROAD DATA DEC. 31, 1922.

Township	Total Road Tax Levy	*(1) *(2) *(3) *(4)	County Road Mileage	State Road Mileage	Township Road Mileage	Bonds	Debt	Valuation
Jackson	.832	(.03-.132-.12-.55)	26.71	7	35.88	$174,109.80	$103,728.64	$4,174,920.00
Clear Creek	.302	(.03-.132-.17-.07)	44.54		26	76,471.70	8,025.36	3,621,870.00
Warren	.482	(.03-.132-.05-.27)	40.24		14	111,566.00	27,550.00	2,968,290.00
Dallas	.642	(.03-.132-.10-.38)	23.68	5	15	123,220.00	54,026.96	2,822,290.00
Huntington	.262	(.03-.132-.10)	40.03	7.75	21	121,576.00	5,754.00	24,475,610.00
Union	.382	(.03-.132-.13-.09)	40.84	2.5	24	68,125.00	15,596.50	4,463,400.00
Rock Creek	.802	(.03-.132-.15-.49)	44.44		26.5	133,737.00	64,188.50	3,733,430.00
Lancaster	.622	(.03-.132-.16-.30)	45.02	4.75	16.5	75,910.00	53,663.90	3,119,110.00
Polk	.672	(.03-.132-.16-.35)	27.16	1.75	17	56,903.40	21,980.90	1,621,410.00
Wayne	.532	(.03-.132- -.37)	30.99	5.75	7.25	94,178.00	37,274.00	2,023,950.00
Jefferson	.680	(.03-.132-.22-.30)	46.80	.50	18.50	113,389.00	42,342.00	2,957,730.00
Salamonie	.672	(.03-.132-.08-.43)	56.58		8.50	201,334.00	96,645.60	4,824,600.00

* NOTE: In the above table (1) went to the State Highway Commission, (2) to turnpike repair, (3) was the township road levy and (4) was for bond retirement.

GRAVEL ROAD MAINTENANCE

By J. T. DONAGHEY,
State Highway Engineer of Wisconsin.

Wisconsin is blessed by nature with a goodly supply of road materials of various kinds and quality, none of which are so valuable as its gravel deposits, especially those throughout the glacial district, covering the eastern and southern portion of the state.

We have over 25,000 miles of gravel roads in Wisconsin. About 5,000 miles of which are what is termed full depth gravel, or from eight to twelve inches. The majority of this mileage is

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found on the ten thousand mile State Trunk Highway System.

The balance is what is termed light surfacing, from five to eight inches in depth. This latter mileage in the majority of cases has been built by the local units of government.

Our experience has taught us that gravel road maintenance must begin the moment the material is in place on the sub-grade. To maintain the surface adequately, the following rules must be followed:

First. Be sure the road enters the winter season in the best of condition. Ditches and culverts must be free and open and the road surface must be smooth and free from holes and depressions that will hold water. Add gravel where needed at this time.

Second. Go over the entire road (surface and ditches) with a twelve-foot blade grader just as soon as conditions will permit in the spring. Move the top inch of gravel back and forth at least twice. This insures removing all holes and depressions permitting the patrolman to begin the season's maintenance work with no handicap.

Third. Add new material at all places where the original material has been pounded into the sub-grade by traffic. Add new material to the entire surface as fast as the original is ground up and blown away. This will be about one-half inch per year for each 200 vehicles per day of traffic.

Fourth. Keep a light mulch of fine gravel covering the surface at all times. The patrolman must move this mulch of gravel entirely across the surface once for each 800 vehicles of travel. As traffic increases, the patrol section must be shortened accordingly and the maintenance equipment increased in weight correspondingly.

Time to Do Work

We begin maintenance work very early in the spring just after the frost has left the ground or as soon as the surface is thawed to a depth that will permit working a blade grader.

At this time the gravel surface is somewhat loosened from the frost action and it is possible to cut off the high places and move them to the low places with more ease and more lasting results than at any other time during the season.

The ridge of gravel thrown outside the wheel tracks by traffic is moved in towards the center of the road with the blade grader and naturally fills the ruts, holes and low places.

All large projecting stones are removed from the surface before adding new material.

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Material

If additional material is needed, it must be made available along the roadside during the winter months and added during this spring work as it will bond much better and more easily than at any other time during the season.

Where new material is needed to fill the holes and low places, use gravel that has passed through a screen having round perforations not to exceed one inch in diameter and containing but a small amount of binder.

When the holes and low places have been filled, the entire surface is gone over thoroughly with a grader having the blade set nearly at right angles, until a uniform and even surface is obtained. The blade is then set at the proper angle to shape up the surface to the proper cross section, which should not permit more than a three inch crown for a twenty-four foot surface. The blade grader or planer is used frequently to keep the ruts filled, assist in compacting the gravel, and smoothing up the whole surface.

Piles of fine gravel for use in maintenance are placed along the road at convenient points outside the ditch line where patrolmen can easily get the material necessary to fill the small holes and defects that may appear from time to time.

The material is delivered to the road by motor truck or on sleighs during the winter months, provided the haul exceeds one mile.

If the patrol man has material available along the roadside he can fill the holes immediately in the spring or after a rain and water standing in the low places will show him better than can be shown in any other way, the exact depth of new material necessary to bring the low places to the proper crown. The best time to add new material is when the holes or low places are filled with water.

Time to Use Grader or Planer

The best results are obtained with the blade grader or planer early in the season, just when the frost is leaving the surface, or after a rainy period of several days, at which time the entire surface has become so thoroughly soaked and softened up that material moved from the high places will bond readily where it drops into the low places.

Motor trucks are used to good advantage for pulling the grader or planer. An ordinary three ton motor truck will pull a blade grader or heavy planer very satisfactorily. This requires an extra man to handle the grader, but the extra expense is offset by this type of equipment being suitable for delivering material to the road.

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Motor graders do excellent surface maintenance work, but are not satisfactory for cleaning out ditches.

We find a good team patrol will cover a six mile section. A motor grader thirteen miles, and a motor truck twenty miles. The team patrol generally being the best and cheapest.

Do not be afraid to use the grader or planer during dry weather on a gravel surface. The material thrown out by traffic should be moved in to asssist in filling the depressions caused by heavy traffic in dry weather. All of the material will not remain in the depressions, but enough of it will to warrant the work. We find on those gravel sections where the patrolman keeps moving the surplus fine material back and forth across the surface, even though the weather is dry, that he invariably has the best riding section.

Scarifying and Reshaping

Hundreds of miles of uneven gravel roads built in the past have been converted into excellent roads for travel by scarifying and reshaping. A roller scarifier or an ordinary heavy grader scarifier pulled by a heavy tractor is used. It is generally advisable to scarify to the entire depth of the gravel or at least to the depth of the deepest holes. Harrow thoroughly with a heavy peg tooth harrow and shape up the surface with the blade grader. The blade should be set nearly at right angles in order to remove the waves and depressions. Remove loose stones from the surface and use the grader or planer daily until the surface is well compacted. Add fine gravel where needed to strengthen the weak places and fill all depressions.

Untreated gravel surfaces that carry an average traffic of 400 or more vehicles per day should be scarified and reshaped twice during the maintenance season. The first time as early in the season as the work can be done and the second time about September 1st. We generally have rains about this season, which will assist in bonding the gravel that has been loosened up with the scarifier. The surface will be in much better condition to go through the fall and spring wet seasons than if the holes and wash boarding are allowed to remain.

Surface Treatments

When traffic reaches an average of 300 vehicles or more per day some form of surface treatment should be applied in order to protect the surface of the road from grinding up and blowing away. Up to this traffic limit there is probably no question but what the addition of the required amount of new material from time to time will keep the surface of the road in very good condition at a lower cost per mile per year than can be done by any form of surface treatment. However, we must consider the

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material lost annually, which is not less than 300 cubic yards per mile for an average daily traffic of 300 vehicles and the danger and nuisance existing from the prevalence of dust.

Calcium Chloride:

The application of calcium chloride or any other dust layer that does not form a surface that will serve traffic without the patrolman's constant attention with grader or planer can hardly be classed as a surface treatment. However, on roads carrying not to exceed 400 vehicles per day quite satisfactory results can be obtained by the application of calcium chloride or similar dust layers. The surface must be shaped to the proper cross section and reasonably well compacted before application. It requires an application of from one-fourth to one and one-fourth pounds of calcium chloride per square yard for the first treatment. Generally a second application must be made about midsummer, requiring from fifty to seventy-five per cent of the first application, making in all not to exceed two pounds per square yard per season. Calcium chloride is applied by the use of an ordinary lime spreader and one outfit can apply two miles or more per day. Calcium chloride does two things; first, it lays the dust quite satisfactorily, and, second, it conserves the material on the road surface, not so much as bituminous surface treatments, but enough to be recognized as a considerable saving per mile per year. It is, however, a dry weather treatment and works out much better during a dry season than it does if the season is especially rainy. During a rainy spell a surface treated with calcium chloride gets quite sloppy and pits easily. It also requires constant patrol maintenance.

There is no question but what this treatment is beneficial, especially upon those surfaces that are not bonded sufficiently to treat with light tar.

Light Asphaltic Oils:

There are certain gravel roads constructed of such material that the surface is always covered with a heavy mulch of fine material that stays bonded for only a short time after each rain. On such roads a light oil surface treatment works out very satisfactorily and at a reasonable cost. The surface must be shaped up properly and the oil applied at the rate of about one-half gallon per square yard. After the oil has penetrated the fine mulch, it should be moved back and forth with a blade grader the same as untreated gravel would be handled, and must be gone over often enough with the grader or planer to keep it from becoming solid or shiny at any point. If there is evidence of it becoming hard and shiny, it is well to apply a small amount of fine gravel and move it back and forth over this portion of the sur-

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face which will prevent such condition. This treatment will conserve the material, prevent dust, and is generally a satisfactory surface for one season. Frequently, however, it is necessary to give a light second application about mid-summer. In this event the cost will be increased to whatever extent is required by the second application. It will not require quite as much material per square yard the second year as the first. However, if no application is made the second year, the surface soon gets in its original condition or worse. In other words, there is no permanent or lasting value in a light oil treatment. The total cost per mile per year, including new gravel but not including patrol maintenance, will range from $400.00 to $500.00 This form of surface treatment is generally satisfactory up to a daily average of 800 vehicles.

Light Tar:

Where traffic reaches an average of 800 or more vehicles per day, the loss is not less than one and one-half inches of surface annually, or not less than 450 cubic yards per mile. Very few localities have enough gravel available to construct and maintain their roads for a ten-year period unless such material is conserved to the maximum. A loss of 450 cubic yards per mile annually would in five years provide sufficient material for a mile of new road. No community can afford this loss.

We use no material in the top five inches of a gravel surface which exceeds a size that will pass a one-inch round opening. This material is not separated, but is all deposited in the same bin and loaded into trucks from a chute in the bottom of the bin. This insures a uniform gradation. The same specifications prevail on all resurfacing of old gravel roads. This costs somewhat more than pit run gravel or gravel crushed to a larger size, but it is worth much more than the difference in such cost, especially where the surface must be scarified frequently.

In preparing for the first surface treatment, the surface is thoroughly scarified to a width of twenty feet or more, and to a depth of the deepest holes appearing in the surface, which is generally not more than two inches. It is necessary to lap the scarifier one-half in order to get the surface completely scarified, as material of this kind becomes extremely solid under heavy traffic and a "once-over" with most scarifiers will not produce the desired results.

Immediately following the scarifier, the surface is shaped with a twelve-foot blade grader to a uniform cross-section. The material is sometimes loose and dusty on account of the fine content, and a sufficient amount of time is permitted to elapse for the surface to become well compacted. A good heavy rain will aid materially. The surface is now swept clean with a rotary

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broom. The sweeper is hauled by a motor truck and leaves quite a windrow of dust and loose gravel, so that a light grader is used to push the windrow out of the way of the sweeper for its second trip. The surface is swept twice, and after the second sweeping the coarser gravel in the surface projects just a little above the rest of the surface, producing practically a mosaic surface. Should there be any dust pockets remaining, they must be cleaned out with hand brooms. Some gravel surfaces may not need scarifying and are shaped up very satisfactorily with a heavy blade grader. This work should be done early in the spring, just as soon as the frost leaves the surface of the road.

Application of Priming Coat:

After the surface is swept clean, the tar is applied as follows:

Light tar equivalent to Tarvia B may be applied cold, but better results will be obtained if it is heated to 100° F. The distributor should be thoroughly cleaned before beginning operations and then kept clean. There should be a double strainer on the distributor tank intake in order to exclude all cinders that may be in the tank car as it is almost impossible to secure a tank car of tar which does not contain some cinders. It is also very necessary to have several extra nozzles so that if one becomes clogged it can be replaced immediately which will permit the distributor to operate evenly. Even distribution is very essential.

The priming coat is applied at the rate of one-sixth to one-fourth gallon per square yard on new surface treatments, and no sand or covering is spread over it. Forty-eight hours or more are permitted to elapse after the priming coat has been applied, during which time traffic irons out the surface in a fairly uniform manner. If the covering must be spread by hand and conditions will permit, immediately following the application of the priming coat the covering for the second coat should be deposited along the shoulder of the road. Be sure that the windrow of loose dust and gravel left by the sweeping has been pushed clear out over the shoulder with a grader before the covering is deposited along the shoulder as the covering material should be located on the shoulder outside of the edge of the surface treated portion and not be permitted to mix with the loose material swept off the surface.

Depositing the Covering Material:

Pea gravel, fine stone chips or clean, coarse, sharp sand is the best material to use for covering, and for a twenty foot surface it will require about fifty cubic yards per mile to cover the surface properly. The covering should be deposited in piles of about one-fourth cubic yard each, and twenty-five feet apart,

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and care should be taken that the inside edge of the pile be entirely clear of the outer edge of the surface treated portion for, if a thin film of covering opposite the piles should be covered with the second application of tar it would pit out at that point and produce very unsatisfactory results.

The reason for depositing the covering in advance of the application of the second coat is that a certain amount of covering must be applied immediately after the second coat of tar touches the surface, which prevents the tar from running off and permits it to penetrate the surface, thereby forming a skin coat and not a mat. The covering if deposited along the shoulder is also available to add immediately in any amount desired to prevent picking up and to cure bleeding.

Application of Second Coat:

Should several days have elapsed before the second coat is applied and the surface has become slightly loosened or dirty, it should again be swept lightly to remove any loose material. The distributor is now set to spread about one-third gallon per square yard and care must be taken to have the tar spread uniformly.

Where the covering is spread by hand a number of men (from six to ten) are stationed along the sand piles from fifty to one hundred feet apart. When the distributor is started along the road, the man at the first pile spreads a little less than one-quarter of the covering in his first pile on the width covered by the distributor opposite the pile, doing the same with the next pile and so on, working rapidly. The second man does likewise when the distributor reaches a point opposite his first pile, and so on down the line of men. The first man, upon reaching the point where the second man started spreading, moves ahead of the line of men, beginning a new station the required distance from the last man in line. Handling the covering in this manner permits applying a small amount immediately after the tar touches the surface of the gravel, and, as stated before, prevents the tar from running off the road surface and assists it in penetrating the gravel, which is what is desired. To do this part of the work cheaply and rapidly, on a large mileage, there should be two or more distributors on each job, one being loaded while the other is distributing. There will naturally be a certain amount of elapsed time between the loads, which permits the sand spreaders to go back and add sand where needed to keep the tar from running off the surface or to prevent picking up. The distance of the job from the supply of tar will, of course, enter into the time question. The other side of the road is handled in just the same manner, and the distributor should be so equipped that two trips over the road will cover adequately the width of surface desired.

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Extreme care must be taken to avoid spreading too much covering on the second coat until it has had time to penetrate the surface. If too heavy a covering is spread, or if the spreaders are careless and dump full shovels in a place, the result will be that the excessive amount of covering will absorb or blot the tar and prevent it from penetrating the surface and will result in a mat rather than a skin coat. The spreaders should use square point shovels and learn to throw the covering from the shovel in a manner that will produce an even application.

If the weather is reasonably warm penetration will immediately take place and after two hours have elapsed there is very little danger if more covering than is necessary is applied as the tar will then have penetrated sufficiently so that the excessive covering will not blot the tar. One or two extra men should be kept on each mile for at least a day or two following the second application to apply covering where the surface starts to pick up or bleed, and a small amount of material should be left in about every third pile for this purpose.

Mechanical spreaders may be used, but if used, not to exceed one-fourth of the total covering required should be spread immediately following the distributor, an additional fifty per cent in about two hours, and the balance as needed to cure picking up or bleeding.

The most practical and convenient mechanical device for spreading sand, pea gravel or stone chips that the writer has seen in operation is in Bane County, Wisconsin. It was designed by the county mechanic. It will spread evenly at the rate of twenty cubic yards per mile of twenty-foot width, or any desired thickness in excess of that. It is very simple, can be attached to any dump body truck and is not expensive to construct or attach.

Patching the Surface:

The patching material is composed of from fifteen to seventeen gallons of light tar equivalent to Tarvia B, mixed thoroughly with one cubic yard of coarse sharp sand. The material must be mixed thoroughly either by hand or in a mixer, and it will give better results if it stands several weeks after mixing prior to being used. The volatile oils evaporate and when thoroughly cured the mixture makes a better patch and will stay in place much better. Patching material mixed the previous year has been used with better results than when used fresh. No more than seventeen gallons of tar per cubic yard of sand should be used even though it is slow in mixing.

Those in charge of maintenance must watch the surface very carefully, especially the first ten days after the surface treatment is applied. If a hole or abrasion appears in the surface the loose material should be swept out clean and the hole filled with

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patching material. If there are any places that appear loose and do not harden up under traffic, they should be dug out to a depth where solid material prevails, the hole filled and the material well tamped in and given an application of tar, and in a few days covered with a coat of patching material. The patch will soon iron out and become equal to the balance of the surface. The patrolman must be sure to fill every hole just as fast as it appears noticeable to the eye, even though it is not more than the size of a silver dollar.

The outstanding points to insure satisfactory results are:

First: Do not add more than one inch of new material during the season in which the treatment is given. In other words, if a gravel road is to be surface treated, any addition in material required in the line of resurfacing should be applied the previous season and permitted to compact during the late fall, winter and spring. However, light applications of one-half to one inch can be made early in the spring and get good results the same season. This material should be placed before scarifying the surface.

Second: The surface must be well compacted and uniform.

Third: The surface must be swept clean.

Fourth: The primary coat must be applied immediately after sweeping.

Fifth: The tar must be uniformly spread.

Sixth: The covering must be spread evenly, and a little less than fifty per cent of the required amount spread immediately following the distributor, the balance being applied later as required.

Seventh: If possible, close the road to traffic for twenty-four hours after the second coat is applied.

Eighth: The surface treatment must be followed up promptly and carefully by the patrolman or maintenance gang and patching material must be added just as soon as the slightest hole is noticeable on the surface. A well-prepared surface should not require more than seven cubic yards of patching material per mile per year.

Ninth: **Unless plans are made to patch every hole the moment it appears, it is better not to attempt to maintain a gravel road with this type of treatment.**

Approximate Costs:

The first tar surface treatment of a gravel road twenty feet wide will cost from $900.00 to $1,200.00 per mile. This includes the necessary preparation of the surface, the follow-up maintenance, and the entire patching cost of the season.

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Preparing the Surface for Retreatment:

Where a road has been previously treated by this method, preparations for retreatment are as follows:

Any portions of the surface that are in perfect condition, showing no holes, ridges or wrinkles, may be retreated without scarifying or breaking up with a blade grader. Under these conditions two to three-tenths gallons per square yard should be sufficient.

Those portions that are slightly uneven should be gone over with a heavy blade grader early in the spring when the tar skin coat is inclined to be loosened up a trifle from frost action and weather conditions, pushing the skin coat out of the shoulder of the road with the grader and following this up with a light blade grader such as is used in patrol work moving the material pushed to the side of the road back and forth across the surface of the road every other day for a week or two. The best results are obtained when the temperature is from 60 to 70 degrees F.

This breaks up the old tar crust and the grader operations smooth up the surface of the road to a point where it is practically a perfect cross-section. When the surface has become smooth and well compacted by these operations it is swept clean and the covering material placed in piles along the edge. The tar is applied in the same manner as outlined above and generally no priming coat is required. Should the surface require a priming coat it should not be in excess of one-sixth gallon per square yard. The coat required for the second year's surface treatment is approximately one-third gallon. The third year and thereafter a less amount is required unless additional width is treated.

The application of tar, spreading the covering, the follow-up patching and everything connected with the work is done just the same as on a new surface treatment.

The Mixing Method

Where the gravel surface contains but little binder and the surface is not well bonded, very good results may be obtained by applying the tar without sweeping the surface. The surface is brought to the proper cross-section with a blade grader and immediately following this an application of one-third gallon per square yard is spread over the full width of the road.

About two hours is permitted to elapse after applying the tar to permit it to penetrate the loose surface. However, traffic can pass over the surface almost immediately following the distributor, splashing but little tar on the vehicle due to the fact that it immediately penetrates the loose gravel surface. Two twelve-foot blade graders are now used to move the top three-

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fourths inch of surface over well beyond the center of the road. Immediately following the second grader the distributor applies one-third gallon of tar per square yard on the solid gravel. Immediately following this the graders push the loose material from the other side over to the opposite side of the road and the tar is spread on the other half of the solid gravel. The loose material is now moved back and forth across the road surface three or four times. The blade is set at about a 45-degree angle in order that it will roll the material along the blade, which assists materially in mixing the tar and gravel. When the loose material has been mixed until it is all coated with tar, it is then spread out with the blade grader to a uniform thickness over the surface. Traffic is permitted to use it immediately; in fact, traffic is never shut off on this type of treatment. A light grader or planer is used continuously until the surface is thoroughly ironed out and well compacted, which will take about two days where travel reaches a thousand vehicles or more daily. Where traffic is less than this amount it will take slightly longer to iron out and become well compacted.

After the surface is well ironed out a seal coat of about one-sixth gallon per square yard is applied, followed immediately with a very light covering of pea gravel. The planer is again put in operation and moves the surplus pea gravel from the high spots to any depression in the surface, resulting in a very uniform and smooth surface within a week or less.

This method requires about five-sixths gallon per square yard and, of course, necessarily costs more than the ordinary surface treatment heretofore described. However, it insures a penetration of approximately one inch and also insures the entire surface being well bonded with tar. We find this type requires much less patching and less attention than the ordinary surface treatment. We tried out a mile of this type in 1923 and it came through the 1924 season without a retreatment. Therefore, at the end of the two seasons it was cheaper than the ordinary surface treatment.

We are very much sold on this latter type and are satisfied that more of our treatments will be along this line from year to year.

Costs

We surface treated 200 miles of gravel road with light tar in 1924, and expect to treat 400 miles in 1925. Dane County alone will treat approximately 200 miles in 1925. After three years' experience in Dane County with tar surface treatments the county board appropriated $150,000.000 as a special fund for the surface treatment of their main gravel roads in 1925.

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It may be interesting to know that Dane County is one of the few wealthy counties in Wisconsin that has not bonded for concrete roads. While I am satisfied that their main roads should be of some high type of surface, nevertheless they are getting excellent results with the surface treated gravel and are satisfying the general public and especially the farming public. The maintenance cost is well under the interest on a high type surfacing and as long as it remains below that point it can be argued that there is no waste of public funds.

In Wisconsin we find it practically impossible to get appropriations sufficient to build all our main lines of travel with high type surfaces, and we do find that we can maintain our gravel surfaces in a very adequate manner with light tar surface treatments giving the public a safe and pleasant road to drive over and conserving our local materials by so doing until such time as funds can be provided for a higher type surface.

STONE ROADS OF MONROE COUNTY

By Prof. U. S. Hanna, Indiana University,
Monroe County Engineer.

Owing to the generally rough and rolling character of the land in Monroe County the roads in very many parts of the rough sections do not follow the section lines, but follow ridges and valleys instead. About one-third of the land is very good for farming purposes, one-third is only fairly good for tilling and pasturing and the remaining third is about as poor as any land in the state, and should be taken by the state and reforested. Thousands of acres in the county are what is called "trading land," and it changes ownership very frequently, when it has ownership at all.

These localities are the farthest removed from Bloomington, where none of the roads have been improved. The lack of wealth and the roughness of the land have made it altogether impossible for these out townships to build any roads under the three-mile road law. Since the passage of the county unit road law we have built and let contracts for about twenty-five miles of roads in these outer townships and there are petitions now on file for about fifty additional miles.

Distribution of Stone

The distribution of limestone suitable for stone roads is pretty general throughout the county, and this fact has made possible the very rapid development of our stone road system. The

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first macadam in the county was broken by hand and placed on the streets around the square in Bloomington about fifty years ago. The first pike roads were built in the face of the greatest opposition, about thirty years ago. And some of the original kickers are still kicking. We now have about fifty miles of improved streets and four hundred miles of pike roads in the county, and the number of kickers is gradually but slowly diminishing. Only a very few would care to return to the primitive conditions, and strangely enough they all live on roads already improved.

There are about sixty locations of quarry sites for macadam, fairly well distributed over the county, and about the same number of quarries and mills operating for building stone. The average haul for delivery of stone on the roads is between two and three miles, the longest haul for some roads being four to five miles. The average cost of stone delivered on the roads now is about $2.25 per yard. The cost of repair work on our three hundred miles of county roads in 1924 was $73,000 or about $265.00 per mile. This does not mean that all of the roads were repaired. Only the most traveled roads and those in the worst need of repair received attention. Many of the roads which have been improved are not repaired at all for the simple reason that repair funds are inadequate. This curtailing of repair funds is due to an honest effort on the part of taxing officials to keep taxes down. It results in half of our roads getting in such a condition in a few years that they must be practically rebuilt at a much greater cost than the cost of repair would have been, if it had been done at the proper time. On the whole, we pay more taxes by having tried to lower taxes at the wrong place, and besides we get much poorer service from our roads in this deteriorated condition.

Many of our citizens make use of the fact that we do not keep our roads in the proper repair in advocating that we should cease the building of new roads. They say, "Why build new roads when we can not repair the ones we have already built?" The error lies in assuming that the repairs can not be made. The tax levy for repairs should be pushed to the limit as a measure of economy. This is true now more than ever before, because of the much more damaging character of the present traffic. If the tax levy for repairs can not be made to meet the requirements then some other means should speedily be found whereby the work can be carried on.

There are really only a few people in the county of a disposition mean enough to want to discontinue the construction of new roads in the outer parts of the county. These rural citizens have been paying loyally for the last thirty years of their hard-earned savings at the same rate as every other citizen of

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the county toward the whole county road repair program, and in that time they have paid in more than the cost of what they are now asking in return.

To complete these roads as proposed and petitioned for will require about sixty miles in addition to what is under contract. The cost will be about four hundred and fifty thousand dollars. Our bonding limit for county unit roads is about two hundred seventy-five thousand dollars, of which about one hundred thousand dollars remains unappropriated. After the limit is reached there will be enough paid off each year to build four miles of average road. From this it appears that it will require from twelve to fifteen years to build the roads now petitioned for. In view of the fact that we have built four hundred miles of fairly decent roads in the last thirty years it would seem that the program of building sixty miles of road in the next fifteen years is not unreasonable, and should not cause a very deep gloom to settle over our good people who already have their pike roads. I am quite certain the people who live way out in the mud will not worry much about it.

Some of our first pike roads were built at a cost of $850.00 to $1,000.00 per mile. Of course, they had fords then in place of bridges and culverts. Most of these roads have been rebuilt two or three times since. The average cost per mile, taking into consideration the fact that many miles have been built two or three times, is probably close to five thousand dollars, making the total cost about $2,000,000.00. Another million dollars cost for new roads, spread out over a period of twenty years, will solve our problem of roads in new territory. Then we can settle down to a cost of maintenance and occasional rebuilding of old roads with new and improved materials and feel that our heaviest burdens of road building are beginning to lighten.

The property within the corporate limits of the city of Bloomington pays over half of the cost of new roads and maintenance. The citizens generally are strongly in favor of going ahead with our program of connecting our improved roads with the improved roads of our adjoining counties. The business men of Bloomington believe in extending the territory served by them and are willing to invest their money in the rural roads as the best means of bringing about this result. As is usually the case, what is best for the rural communities in a county is best for the county seat and vice versa.

In the construction of county unit roads now under contract we are expending from fifteen hundred to three thousand dollars per mile on bridges less than twenty foot span, culverts, clearing and grade twenty-two feet wide with maximum gradient of ten per cent. In two instances so far we have been forced to

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a maximum of eleven per cent in our plans. This maximum will doubtless seem rather high to many of you, but I may say that we have a number of hills in the county, on roads improved years ago, with gradients running up to eighteen and twenty per cent. One of these, Tabor Hill near Gosport, which for many years was used for advertising tests of automobiles, is eighteen and one-half per cent.

The state highway engineers are now making surveys for the purpose of getting away from a lot of these steep hills in our county on state road No. 22. It looks as though they might have to relocate the road for almost the entire distance through the county if they are to secure as low a maximum gradient as roads with such heavy traffic should have.

Construction Methods

We do not find it necessary to roll the subgrade. The stone is hauled to the road in five-yard trucks weighing twelve tons loaded. The wheel treads are fourteen inches and drivers are bound to distribute the bearing well over the subgrade to prevent it from rutting. The subgrade is crowned an inch and a half to two inches on the center twelve feet and six to seven inches from the center line to the ditch.

On the subgrade we place a nine-inch layer of stone twelve feet wide of sizes to pass a three-inch ring, from which enough screenings have been removed to make a top layer of four inches. The character of the stone has very much to do with the amount of screenings made. The fineness of the crushing should be such that will yield strong four inches of screenings rather than scant four inches. The cost of the stone is close to a dollar a lineal foot.

We use thirteen-inch boards with thirteen-inch pins in the center, the pins being set after the nine-inch layer is placed so the trucks will pass over them. The screenings' course is kept up close to the first course, neither course being rolled. We do not bank the boards at all, and when they are removed the edges of the stone are raked outward one foot on each side. This bevcling makes it easier for traffic to get on and off the stone and the traffic helps in widening the stone, which in time comes to be about sixteen feet.

Three or four times during construction the wheel ruts in the stone are filled by using the grader and during the first year after completion the county road superintendent frequently runs the grader over them to smooth them up. In a year's time the traffic will have found the road in fairly good condition. The people in most localities where we are building them seem very much pleased to get them without the expense of rolling and

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water-binding. We are convinced that we are getting some very good roads at a minimum cost.

In cases of rebuilding roads carrying very heavy traffic, where the width required is eighteen to twenty feet, we have built water-bound roads, perhaps fifty miles in the county. It is only a very short time until the process of traffic binding has to start and be kept up the same as on the roads that have been traffic bound from the first and without the added cost. If the traffic on a road justifies water-binding, then it justifies the additional expense of putting on some wearing surface to take the wear of traffic.

We believe that the methods of maintenance followed in our county by the State Highway Commission's maintenance department are the best for our roads and we are following their plan as far as possible to do so on our old roads in repairing them. We have a most excellent road superintendent and one who is very skillful in making the funds hold out and spread out over the 300 miles of roads, but he should have at his disposal twice as much as he has.

The greatest damage to our roads is brought about by erosion, owing to the high gradients so frequent throughout the county. This condition is always accompanied by very low tax values and the two do not make a very happy union.

We are much inclined to the belief that the state should increase the road mileage in the state system to ten thousand miles and help the poorer localities in the state get better roads.

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NEW DEVELOPMENTS IN MAINTENANCE OF CONCRETE AND BRICK ROADS

By A. H. HINKLE,
Supt. of Maintenance, Indiana State Highway Commission.

Large sums of money are being invested annually in the construction of concrete and brick pavements. It is important that the most economical means of maintaining and repairing such pavements be determined and put into practice in order that these large investments shall be protected. It is important that every type of road be properly maintained. Unless it is contemplated to properly care for the more costly types of pavement, we can not justify ourselves in building them.

Although the highways are now a controlling factor in our modern civilization and the transportation feature of them is the big development which stands out most prominently and is most impressed upon the general public, yet it is imperative that many little technical details be learned and put into practical effect in order to economically build and maintain a system of good highways.

A number of people throughout the country are now devoting much of their time to a study of the best methods of maintaining such pavements. Almost every year finds some new discovery, or perhaps we better say an old discovery put into practical application, in the maintaining and repairing of our highways. We are doing this year what was never thought of a few years ago or what was done only in a haphazard or an experimental way.

In a discussion of the subect of this paper, I will try and describe briefly some features of this work which are more or less new or which I consider very important in ordinary practice in doing highway maintenance work. The larger part of the paper, however, will be devoted to a discussion of making concrete repairs with quick hardening concrete. The use of such concrete will be a great advantage to the general public in that a road need not be closed long to traffic because of the repairs.

A. Filling Cracks and Joints

Monolithic types of pavement are all subject to cracking. While these differ greatly in degree they are not necessarily any serious detriment to the pavement. Observation will show, however, that usually the more frequently the cracks are found the more defective is the concrete or the poorer the sub-grade.

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The cracks and joints in such pavements should be sealed about twice a year so as to keep the pavement water-tight and thus prevent, so far as possible, water from reaching the subgrade. Also, the cracks should be filled to prevent the edges from raveling.

Our experience would indicate that the most suitable material for filling such cracks is asphalt meeting our specification for Emulsified Asphalt A. E.-1 or tar meeting our specifications for Tar T. P.-2. The former material is used cold while the latter has to be heated before it is poured into the cracks.

Both materials are covered with coarse sand, or stone or slag about ½ inch in size. The bituminous material can best be poured into the cracks from a small pouring can preferably not exceeding two gallon capacity. A small can will aid in preventing the use of too much of the asphalt or tar which is very objectionable. The use of an **excess of the bituminous material** will build up a ridge across the pavement which is quite as objectionable as the unfilled crack. In addition to the neglect to fill the crack, I know of no more frequent mistake than the persistent use of an excess of the bituminous material. The crack should be just filled with the asphalt or tar which should be permitted to lap over on the spalled edges of the concrete no farther than is necessary to merely protect same. **Experience and observation will soon teach one how much material to use.** After the filler has been subject to traffic for a few days, the crack filler should project above the level of the pavement no more than ¼ inch. The filling of the cracks **can be** properly done if a little care is used in the work. Too frequently the work is done with the grossest carelessness.

Because the filler is splashed out of the crack by traffic going over it just after it is poured, it is desirable on a heavy traffic road to fill the cracks in but one side of the pavement at a time. The filling operations themselves will keep the traffic off the newly filled cracks for a short time which is usually all that is necessary.

The repair of cracks in Monolithic brick pavements can be made in the same manner as cracks in concrete pavements.

Emulsified asphalt, if subjected to freezing temperatures before the water evaporates, will be injured and hence it can not be successfully used during the winter season. **Very small** cracks may be filled during the **winter season,** with cold tar meeting with our specifications for Tar T. C. M. This grade of tar cannot be successfully used to fill cracks in its pure state during the summer season as it is too liquid and will readily flow from the cracks.

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Where the **cracks are sufficiently wide** the edges should be painted with one of the above grades of bituminous materials and then tamped full of bituminous concrete made by mixing either emulsified asphalt AE-1 or tar TCM with a graded stone. The maximum size of stone should be no greater in diameter than 2/3 the width of the crack or the depth of the depression to be filled and should be graded down to ¼ inch size. If tar is used to make the mix it should contain practically no dust and little material that will pass the ¼ inch. If the asphalt is used, 10 per cent to 20 per cent of the stone may pass the ¼ inch and a **small** amount of dust is not objectionable. If there are visible voids in the mixture used to fill the cracks after same are tamped into the crack, they may be filled with a paint coat of the emulsified asphalt or hot tar TP-2 and covered with sand.

B. Surface Disintegration or Depressions in the Surface

Very shallow disintegrated areas may be painted with emulsified asphalt or the hot tar and covered with coarse sand or stone or slag screenings. If the depression is of any appreciable depth, after the surface is painted, it should be built up to the proper elevation by tamping into the paint coat one of the bituminous mixtures mentioned above. For this latter purpose rock asphalt or any one of the hot mix bituminous concretes may also be used.

In making such patches it is exceedingly important that the surface be brought to a true and uniform grade so as to have, when completed, a smooth riding surface. A straight edge should be applied parallel with the line of the traffic to aid in determining the smoothness of the surface. It is also important that no great excess of bituminous material be used in painting the old surface and that the **minimum** amount of the bituminous material be used in the mixture in order to reduce as far as possible the possibility of the surface waving and rolling under future traffic.

C. Sub-grade Defects—Base Failures

It is not uncommon to find the pavement failing because of a poor sub-grade consisting of clay which saturates badly by capillary attraction. This is frequently a difficult problem to solve. Every effort should be made to drain the sub-grade as frequently springs are found in such clays. Besides having suitable side ditches, french drains can be constructed in the shoulders extending from about 1 foot below the lower edge of the pavement to the side ditches. If these fail to properly drain the sub-grade, the slab will frequently break up in time after much heavy trucking has gone over it. These breaks produce what are

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known as a "base failure." Such failures frequently can not be prevented on such clay soils unless a layer of stone, gravel or cinders is placed upon the sub-grade before laying the pavement or the slab made thicker over such soils.

In repairing such base failures it will usually be desirable to make such repairs with quick hardening concrete as described in the next part of this paper.

D. Repair of Concrete (Portland Cement) Pavements with Quick Hardening Concrete Made with Ordinary Portland Cement

1. Importance of Doing Good Work

Where it is desirable to open the patch to traffic as soon as possible after it is made, it is necessary that a concrete be used that will attain strength rapidly. Since the patches are usually small, and hence small amounts of concrete are wanted at intermittent periods, there is much greater danger of making a poor concrete patch than a new concrete slab in the original construction, unless great care is taken in doing the work. Inasmuch as it is desirable to make a stronger concrete and one that will attain strength quicker than in a new pavement, it is extremely important that we comply with every detail for making a good patch, from the preparation of the sub-grade to the finishing of the surface and protecting it against traffic until sufficiently strong. Unless the work is so done as to comply with **all the requirements to make a perfect** repair it is far better that the repair be made with something else than concrete.

2. Cutting Away the Old Concrete

This can be done with picks, chisels, crowbars or jack hammer drill. The use of a paving breaker operated by a small portable air compressor is the most practical method if any quantity of work is to be done. All the broken and disintegrated concrete should be removed and the old slab cut back until solid, rigid, concrete is reached which has on top a smooth and uniform surface. The top edge of the old concrete should be trimmed by hand (with the use of hammer and chisel) to a uniform and vertical edge for a depth of about one inch below the top surface. The remainder of the vertical edge of the concrete should be left as rough as possible. The base of the old concrete should be thoroughly brushed to loosen any spalled concrete.

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Fig. 1. Cutting away the old concrete with a paving breaker operated by portable air compressor.

3. Preparing the Sub-grade

The sub-grade ordinarily should be excavated to a greater depth than the original slab. At its junction with the old pavement the new slab shall be increased 4 inches to 6 inches deeper than the thickness of the old slab. Also, the new concrete should extend back under the edge of the old slab (see Fig. 2). The depth of the new concrete should depend upon the nature of the subsoil. The old concrete slab has failed for a reason. Quite frequently this reason will be found to be the soft clay subsoil. Therefore, the thinnest depth of the new slab should usually be 2 inches to 4 inches deeper than the old pavement. In very bad spongy clay soil, not only should the depth of the new slab be increased but it is also an added factor of safety to tamp into the sub-grade a 3 inch to 4 inch layer of cinders, gravel, or broken stone with an outlet to the side ditch, as shown in Figure 2.

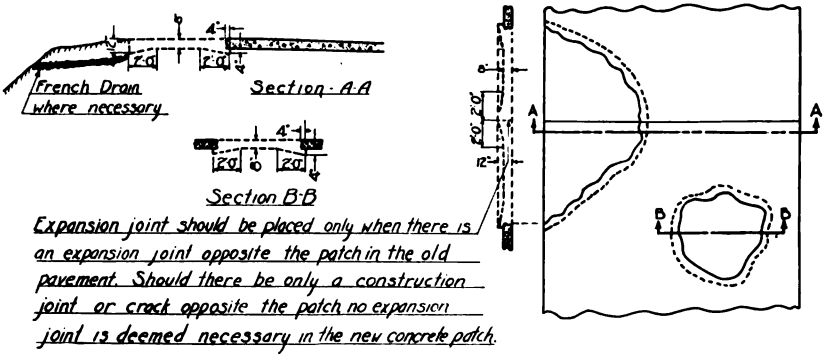

French Drain
where necessary
Section A-A
Section B-B
Expansion joint should be placed only when there is an expansion joint opposite the patch in the old pavement. Should there be only a construction joint or crack opposite the patch no expansion joint is deemed necessary in the new concrete patch.

Fig. 2. Detailed plans for repair of concrete slab.

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This will reduce capillary action in the clay and also help drain the surrounding sub-grade.

4. Composition and Proportion of Concrete

The concrete for the patches usually should be of a better grade than that used in good new concrete paving construction and it should be a concrete that will attain strength quickly so as to accommodate traffic with little delay. If large areas are to be replaced economy would usually require a mix no richer than the standard mix concrete for paving. If only small areas are to be patched wherein the quantity of concrete involved is small, the added cost due to using a richer mix would not be so important an item. The time that traffic should be kept off the patch will determine the mix that should be used. The quick hardening concrete will depend for its early strength upon: (1) Richness of the mix; (2) freedom from excess water; (3) use of $CaCl_2$; (4) comparatively high atmospheric temperatures, and (5) coarse sand and properly graded sand and coarse aggregate. All of the above factors affect the time of hardening of the concrete mix. If we combine the most favorable features of all the above factors in one mix, we can make a concrete which assumes as much strength in two or three days as the ordinary concrete mix used in paving assumes in 21 days.

Traffic should be kept off the patch the number of days shown in Table I (page 59). During cold weather, traffic should be kept off the new concrete a longer period than given in the table as concrete **gains strength slower at low temperature.**

Cement should be tested at the laboratory and a report secured so as to know that it passes the required test. It is imperative that the cement is of good quality. Old cement that has lain around in a damp place until it has partly caked should not be used for **this** most important work. Some brands of cement attain greater strength than others at an early date. It is desirable to use such cement for repair purposes, if it can be conveniently secured.

Sand should be a comparatively coarse sand, 95 per cent of which passes ¼ inch mesh screen. It should be clean and free from silt or foreign material. The sand grains should be composed of hard gritty material and be what is ordinarily known as a "sharp" sand. Sand from many local banks, which, though graded fairly well, contains a large percentage of soft particles, is not desirable as it may produce a concrete which will not withstand the abrasion of traffic. Any amount of **shale in the sand** is detrimental to it and may cause failure of the concrete.

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TABLE I.—SHOWING THE MIX OR PROPORTIONS OF MATERIALS TO USE TO SECURE CONCRETE THAT CAN BE OPENED TO TRAFFIC AFTER ANY NUMBER OF DAYS.

1	2	3	4	5	6	7	8
	PROPORTIONS						
Days Patch Closed to Traffic	Bags of Cement	Cu. Ft. of Sand (0 - ¼")	Cu. Ft. of Coarse Aggregate (¼" - 2½")	Lbs. $CaCl_2$ or Qts. of "Standard Solution"	WATER Add enough to produce Slump given below	Bags of Cement per Cu. Yd. of Concrete	REMARKS
2	1	0.5	1.9	2	1"	11.8	This mixture to be used for small patches that are to be opened to traffic at the earliest date possible. Atmospheric temperature should average about 60° F.
3	1	0.6	2.1	2	1"	11.2	
5	1	1.0	2.7	2	1½"	8.4	
12	1	1.3	3.0	2	1½"	7.6	
15	1	2.0	3.0	2	1½"	6.8	
21	1	2.0	3.0	No $CaCl_2$	2½"	6.8	Standard Mix to be used where closing road to traffic is not an important item and where large areas are to be patched.

(5) This "Standard Solution" is made by dissolving commercial $CaCl_2$ in water at the rate of one (1) pound to enough water to produce one (1) quart of solution. The pure $CaCl_2$ should never be added direct to the drum of the mixer. The "Standard Solution" should be added to the water just before it is put into the drum. See instructions under Calcium Chloride.

(6) Standard Slump Test. Fill with concrete a metal form shaped as a frustum of a cone. Form should be 12" high with a 4" top diameter and 8" base diameter. Set the form on a level surface and as the concrete is put in the form, tamp lightly with a rod until a slight film of mortar appears on the surface. Then remove the form and immediately note the settlement or slump of the concrete which is a measure of its consistency.

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Coarse Aggregate should be crushed stone or gravel fairly **well graded** from ½ inch to 2½ inches in size. If the concrete is to be used to fill a crack or very small opening, the maximum size of aggregate will have to be reduced accordingly. It is imperative that this coarse aggregate be clean and free from pieces of wood, dirt, silt, **shale,** or any soft particles. **Rock of shale formation, although apparently hard and sound when first quarried,** will cause failure of the concrete even though found in comparatively small quantities in the concrete.

Calcium Chloride will be furnished in 100 lb. bags, which must be kept closed as the exposure of the calcium chloride to the air will permit it to absorb moisture from the air and become liquid. It is quite important that the exact quantity of this material be used in each batch. An excess will weaken the concrete and insufficient calcium chloride will not hasten the time of setting to prevent the pavement from being injured by traffic when opened after the number of days given in the table. The calcium chloride must not be added directly to the drum as small undissolved particles remaining in the concrete will cause the concrete to disintegrate. The calcium chloride shall be added in the form of a "Standard Solution" made by thoroughly dissolving one pound of commercial calcium chloride in enough water to produce one quart of solution. (This is at the rate of about 2½ quarts of the $CaCl_2$ to one (1) gallon of water.) This "Standard Solution" should be placed in a keg, jar, or barrel and labeled "Standard Solution." Two quarts of the solution for each bag of cement should be added to the mixing water just before it is put into the drum.

Water must be pure and free from vegetable acids. The amount of water will have to vary so as to make the concrete of the proper consistency. In practice this will usually be found to vary from 2 to 5 gallons of water per sack of cement. However, when all the aggregates are thoroughly saturated with water after a rain it may be found that 2 quarts of "Standard Solution" will be sufficient water to make the required consistency. It should be remembered that excess water will reduce the strength of the concrete and delay the hardening process and not only permanently weaken the concrete, but also lengthen the time traffic will have to be kept off the patch. In order to secure the quick hardening effect, the concrete will have to be a sufficiently dry mix that it will show no more than the slump given in Table I. (See description of slump test in footnote after Table I.) Great emphasis should be placed on the importance of guarding against using **too much water.** The use of 3 or 4 pints more water than is necessary in a one-sack batch will reduce the strength of the concrete more than it can be increased by ex-

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tending the time of mix. Hence, while it is necessary to use enough water to make a concrete plastic enough to be worked and properly finished, **guard against using too much water.**

5. Dampen the Sub-grade and Old Concrete

The sug-grade and old concrete with which the new concrete comes in contact, should be wetted before the new concrete is placed. The sub-grade should be damp but not soft or sloppy. The edges of the old concrete should be saturated with water. It is **very imperative, however, that no free water be present when the new concrete is applied,** as the concrete that is to be opened to traffic soon after being placed depends largely for its quick strength upon having no excess water.

6. Mixing Concrete

Only **machine mixed** concrete should be used. It is almost impossible to get a maximum strength concrete, which is very imperative in repair work, if one depends on hand mixing. The usual time specified for mixing ordinary concrete in a mixer is one minute. However, tests show that the **strength** of a **dry mix** may be increased as much as 10 per cent by mixing one and one-half (1½) minutes, instead of one minute and the strength is slightly increased by extending the time to five (5) or ten (10) minutes. Hence, in repair work and where a small mixer is used, which will generally be less efficient than the big paving mixers, and where a dry mix is required for a maximum strength and quick hardening concrete, the time for mixing might well be placed at not less than **two (2) minutes.** This increased time of mixing will also make the finishing easier.

7. Placing and Finishing Concrete

Concrete should be shoveled in place and **thoroughly tamped** in layers not exceeding three (3) inches in depth. The secret of the early strength of the concrete will largely lie in a **comparatively dry mix hammered in place.** A 10-pound concrete tamper can be used for much of this work. A thin edged tamper having a face, say, 1″x6″ should be available for tamping in narrow openings and along the edge and underneath the old slab.

The concrete shall be finished with a straight edge and a wood float, to a regular and uniform surface to comply with the edge of the surface of the old pavement and the side forms. The straight edge should be used both transversely and longitudinally on the new concrete where the patch is not too long to do so. Where a full width of pavement is being replaced for a length greater than it is practical to use a straight edge, a templet cut to the proper crown of the road should be used. This templet can be used both as a cutting edge and tamper to produce a

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uniform surface. At either end of such a patch or straight edge should be laid longitudinally to insure a proper and uniform junction of the new concrete with the old pavement.



Fig. 3. Finishing the concrete patch. Great care must be exercised in this part of the work to secure a smooth riding surface.

8. Completing Patch at End of Day

Since in making these patches we are dealing with a quick hardening concrete, it is desirable that a patch be entirely completed before leaving it for any length of time. Due to difficulty of shaping up the surface to conform with the old concrete slab with a dry mix, a patch should be entirely finished soon after the concrete is placed. It is necessary that a patch be entirely completed, including the finishing, at the end of a day's work.

The foreman should so plan his program that he can do other work for a fraction of a day if he has not time to entirely complete a patch before his workmen will quit work. Where large areas are being placed, a form board should be set vertically at the close of the day's work and the patch, including the finishing, completed to same as is done in the proper construction of a new pavement. No feather edge junction should be permitted. Owing to the fact that we are dealing with a quick hardening concrete when using calcium chloride, it is necessary to do the finishing **promptly after the concrete is placed** and tamped. After the concrete hardens to any extent it is almost impossible to make a smooth finish. It is important that the template and straight edge be used on finishing a partially completed patch so that the surface of the road will conform with the proper crown of the road and the old concrete surface.

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9. Protecting New Concrete Patch While Curing

The newly laid concrete should be protected against any and all kinds of traffic the number of days specified in the Table on page —. It is desirable that extremely heavy trucking be kept off the patch longer than this, particularly if the concrete is laid in cold weather as the concrete will harden slower in cold weather. The new concrete should be covered with six inches of earth or a layer of straw or sawdust, which should be kept dampened with water. Such covering should be kept on the new concrete about 2/3 of the length of the time traffic is required to stay off of same. The concrete should be protected against freezing the same length of time.

E. Cost of Concrete Repairs Made of the Quick Hardening Concrete Made of Ordinary Portland Cement

It will naturally cost much more to make concrete in small quantities as used in repair work than it will cost to make it in large quantities. Also the cost of cutting out the old concrete and making the excavation for the patch will be considerable. Furthermore, because of the variable conditions encountered with the different pavements being repaired, the costs will vary much more than in new work.

The best **approximate** cost data that we have been able to secure this past summer in making patches 9 inches deep of the quick hardening concrete made of ordinary Portland cement is as follows:

First Job	Per Sq. Yd.
Cutting out old concrete and making excavations	$0.83
Materials delivered (aggregates, sand, cement, $CaCl_2$)	2.70
Labor (excluding making excavations)	1.44
Total cost per square yard	$4.97

This cost includes 10 per cent added for equipment charge.
Second Job.—$3.10 per square yard. No excavation.
Third Job.—$3.10 per square yard. No excavation.

F. Aluminate Cement

A new brand of cement known as Aluminate cement has recently been put on the American market. This cement attains as large a per cent of its full strength in 24 hours as ordinary Portland cement attains in 28 days. For this reason it is very suitable for making repairs where quick strength is required. However, at the present prices quoted, it will cost more to make

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concrete from this brand of cement than it will to make quick hardening concrete describe above from ordinary Portland cement. It is hoped that this brand of cement can be reduced in price and that the concrete made from it will not disintegrate or lose strength with age.

G. Blow-ups

Concrete slabs and brick pavements with grout filler occasionally rupture due to high compressive stresses caused by the combined expansive action of heat and moisture. Such ruptures are usually called "blow-ups" and almost invariably occur on a very hot day in the spring of the year when the subgrade is still saturated. The wetting of the pavement from above by a summer shower which is followed by a hot sun produces a maximum condition of expansion which causes the blow-ups to take place.

It is a well-known fact that the better and denser grades of concrete are not only stronger to resist the forces due to expansion, but are also more resistant to absorption and are much less liable to be destroyed by temperature and moisture stresses.

Where such ruptures as described above occur, it is usually desirable to remove the injured concrete and replace it with new concrete as described under heading "D" above.

Where a brick surface has blown up it is advisable after the base is repaired to replace the brick with bituminous filler to provide for future expansion of the pavement and thus aid in preventing future destruction of the pavement by the same means.

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COUNTY PATROL ROADS AND THEIR MAINTENANCE

By S. N. JOHNSON,
Clinton County Highway Superintendent.

There are 54¼ miles of state highways, 840½ miles of county roads, and 56 miles of township roads in Clinton County. Of the county roads 81½ miles are designated as patrol roads, and the balance are divided into 32 districts, each under the supervision of an assistant superintendent.

The 81½ miles of patrol roads constitute a system of nine patrol roads each under the supervision of a patrolman appointed by the highway superintendent.

By referring to Acts of 1921 we find in substance the following:

"Annually, thirty days before the time for fixing the road repair levy the highway superintendent shall indicate to his assistant superintendents which roads shall be maintained by patrol methods."

We have gone a step further, by designating to the board of county commissioners and county council which roads we wish to patrol, and ask for a special appropriation for these roads. These roads are designated and an estimate of cost is filed with the county auditor at some time before the August term to be acted upon at the September term of commissioners and at the annual meeting of the county council.

The estimate filed at the first and subsequent terms was as follows for sixty miles of roads:

Labor	$14,400
Gravel	11,520
Culverts and repair of bridges	1,560
Equipment	1,800
Miscellaneous expenses	720
Total	$30,000

In December of each year, patrolmen are appointed whose duty it is to reconstruct, maintain and keep these roads in good condition at all times.

While these men work under my direction, the details are left largely to their judgment. They do not look upon their work as a mere job for so many hours per day, but take pride in trying to keep their patrol roads in the very best condition possible.

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This system originated early in the year 1922 when a delegation living on or near patrol road No. 1 presented a petition of some three hundred signatures stating as a claim for patrol maintenance that this road was through a part of the county in which there were no railroads or traction lines and would connect the city of Frankfort with state road No. 29, thereby furnishing an outlet for transportation for this party of the county. The board of county commissioners and myself were asked to designate this road for patrol maintenance. They were informed at this time that there were no appropripations for patrol methods, but that we would continue the subject until time for making a special appropriation for this road. Members of this delegation personally interviewed each member of the board of county commissioners and county council during this interval.

At this time I conceived the idea of a county patrol system for Clinton County and designated six of the heaviest traffic and oldest roads of the county, making a total of sixty miles which connect most of the towns of the county with Frankfort, the county seat. Since patrol No. 1 was sure to be designated I selected the other five roads without consulting any of the parties living on these roads as I thought I had my routes fixed so as to accommodate the most people.

After these roads were established and announced in the press, it was reported that the road superintendent would appoint policemen to police these particular roads, which was considered a joke at that time, but now a necessity in some parts of the country.

Our estimate for these roads covers resurfacing, draining and maintaining for a period of three years.

In March, 1923, we received our equipment and began our maintenance by using a maintainer in cutting out the waves and high places from the roads and filling the low places. We have kept up this maintenance at regular intervals when the roads were in condition for such work and the weather would permit. Our other maintenance has been in resurfacing with gravel during the season fit for hauling. Other work has been general, such as widening grades, repairing bridges, installing culverts and drainage.

Before these roads were designated petitions were filed with the board of county commissioners asking them to rebuild these roads or parts of them, by letting contracts and selling bonds. But these roads are now in such good condition that the persons living on or near them are satisfied with the present maintenance and are not wanting them rebuilt by contract. These petitions will not be continued any longer.

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On patrol roads Nos. 7, 8 and 9 we are ready to begin work, and now every town in the county, except one, will be connected with the county seat, Frankfort, by a state, hard-surface, or a county patrol road or a combination of the three.

At the time I was appointed to this office the business men of the city of Frankfort were not satisfied with the roads leading to their city, saying their business was drifting to other towns on account of the condition of the roads, but at this time I hear no complaint of their condition, and they are highly pleased with this system of maintenance.

After maintaining this system of sixty miles of roads for one year, they broke through in just two places in the spring. These places were soon repaired, as we keep stock piles of gravel at convenient places along these roads. Heretofore, these same roads were always impassable in a number of places in the spring and continued so for some time.

The following table gives you some idea of the amount of labor on these patrol roads and the cost of the same:

Items	1923	1924
Resurfaced	24.1 Miles	26.5 Miles
Graded or dragged	2,347 Miles	2,245 Miles
Gravel placed on surface	10,817 Cu. Yds.	10,314 Cu. Yds.
Labor cost	12,313.29	11,123.62
Gravel cost	7,467.08	7,525.16
Total cost	$21,786.59	$20,687.88

Clinton County has a valuation of $67,000,000 and the rate for the repair of roads is fifteen cents on the $100.00.

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CONTRACTORS' PROBLEMS

By W. M. HOLLAND,
Executive Secretary, Indiana Association of Highway and Municipal Contractors.

This occasion, when linked with the subject assigned, affords me an excellent opportunity to acquaint public officials and some of our state educators with the contractors' viewpoint of the construction industry, the second largest industry in America, ranked only after agriculture. I shall not burden you with a detailed statement of the contractors' problems, for they are many and varied, but rather I shall confine myself to a review of problems which appear to me to be paramount with Indiana contractors in general.

The responsibility of the contractor as gaged by the surety bond, the present cumbersome method of appeal to the Indiana State Tax Commission on proposed bond issues, and the evils of day labor or force account work, are vitally important subjects, and are of such nature as to warrant our joint consideration.

With the advent of large road building programs in this country there came gradually and quite naturally a corresponding increase in public lettings and an equal, if not proportionately greater, increase in the number of contractors desirous of doing public contract work. Consequently the contractor is today engaged in a highly competitive business—competitive, gentlemen, without the slightest degree of regulation. The bidders' field is a melting pot. The experienced, the responsible, the well-equipped contractor is competing with the inexperienced, the irresponsible and the ill-equipped contractor without any recourse whatever. Unfortunately public officials in general seldom have the privilege, without statutory restraint, of selecting a contractor from among competitive bidders, even though previous defaults on the part of irresponsible contractors and delays experienced by public officials through such defaults, create a decided preference for a contractor of skill, integrity and responsibility. "The lowest responsible bidder" is the statutory restraint, and, although some of our courts have liberally construed this phrase, the prevailing idea among officials, taxpayers and others is that the lowest responsible bidder is the one who submits the lowest bid and can provide a bond. "And can provide a bond" brings us to a consideration of the surety companies and their attitude toward this most important problem.

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At the fifth annual meeting of the Associated General Contractors of America in Chicago, January 24, 1924, the relation of surety companies to the construction industry was discussed at length, and the following resolution adopted:

"WHEREAS, Bond agents are writing bonds for contractors, who are obviously incapable of performing their contracts, or who have obviously demonstrated that they can not be relied upon to carry out their obligations in good faith; and

WHEREAS, The bonding of these irresponsible contractors gives them an unwarranted credit rating, and in the eyes of the public, stamps them as responsible bidders; and

WHEREAS, Once this false stamp of responsibility is given by the bonding company to an irresponsible bidder, the engineer or architect is often obliged by a misguided public opinion to award him the contract; and

WHEREAS, The ease with which the surety bond may be obtained by almost any agency designating itself as a general contractor, enables innumerable persons to embark upon extensive construction projects which they can not carry through to successful completion.

WHEREAS, Numerous defaults of these irresponsible companies who can obtain surety bond bring public censure upon the engineer, dissipate engineering funds, produce an inferior quality of workmanship and keep public construction in a demoralized condition; and

WHEREAS, These numerous defaults have greatly increased the rate of bond premiums, thereby adding to the cost of construction paid by the public; and

WHEREAS, Operations of these injudiciously bonded bidders react injuriously upon these contractors who faithfully perform their obligations, create suspicion and distrust of all contractors and retard the development of companies that are willing and able to render satisfactory construction service; and

WHEREAS, The bonding of bidders unqualified by either experience, personal integrity, or financial soundness, to assume their contracts is preventing the development of constructive service, and the adoption of ethical practices which are essential to the establishment of construction as an orderly industry; therefore, be it

RESOLVED, That the Associated General Contractors join with the American Association of Highway Officials and representatives of the surety companies for a complete and impartial analysis of the bonding situation, seeking to find a proper solution for the issues confronting both the bonding companies and contractors."

Subsequent to the adoption of this resolution and during the year of 1924 several joint conferences were held under the auspices of the Associated General Contractors of America with the Surety Association of America, American Highway Officials' Association and others. The sole and only purpose of these conferences was to find a solution for the present evils in the writing of contract bonds, and in spite of the fact that the evils of present practices were openly aired and frankly admitted, the solution has not yet been established. At one of these joint conferences the latter part of 1924, a rather significant committee report was

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made; especially significant when we consider that the committee was representative of the industry. Its chairman was president of one of the leading surety companies, and its membership was made up of the vice-president and the general manager of the Associated General Contractors of America, and the chief engineer of the Pennsylvania State Highway Department. The report in part follows:

> "At the outset, this Committee desires to emphasize the fact that in a real and vital sense the interests of the contractors, the surety companies, and the owners who are having work done are identical. When a surety company writes a bond for a contractor, the surety company and the contractor become in effect partners. If there is a default, the owner suffers delay and other consequential losses not covered by the bond. The contractors, the surety companies, and the owners are therefore interested in the establishment of conditions under which defaults are least likely to occur. A default means loss for all three parties concerned.
>
> "This Committee desires further to emphasize the fact that at present conditions are not satisfactory. Practically any contractor, whatever his financial standing, whatever his experience or lack of experience, whatever his equipment, sufficient or insufficient, whatever the relation of his liquid assets to the amount of work he has on hand, whatever the extent to which he has become over-extended, can obtain a bond. Some surety company will execute a bond for him, and he goes from one company to another till he gets what he wants. The irresponsible contractor can usually find some company to go surety for him. This is the result of competition."

It was said not long ago by a prominent surety official that there are today $45,000,000 worth of contracts—highway contracts—in default in five states. A condition of this kind has a demoralizing effect on the industry, to say the least, and benefits to the public, however great, can be only transitory, whether the condition obtains here or elsewhere, since the condition itself is decidedly unsound.

At a recent meeting of the National Research Council in Washington, D. C., Mr. Frank Page, chairman of the North Carolina State Highway Commission, reviewed the conditions to which he attributed North Carolina defaults (and there were many). In conclusion he said:

> "All losses by defaults and unfinished contracts, whether made good by bond or not, are eventually paid by the State in its continued highway program. These losses are reflected in the higher prices of responsible contractors. It is therefore necessary for the highway officials to reduce their losses. I am therefore contemplating a plan of careful investigation of all bidders by our own department before the contracts are awarded, and the cessation of replying on surety bonds to protect us after the contract has been awarded."

The time must come when a bonding company knows and can prove that its bond is a guarantee of the skill, integrity and responsibility of the assured, and the public will learn then that

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a bond accomplishes its object without quibble and subterfuge, which it does not do under present-day practices.

Appeal to Indiana State Tax Commission

The present cumbersome method of appeal to the Indiana State Tax Commission on proposed bond issues inflicts a hardship on the contractor over which he has absolutely no control. The Indiana State Tax Law as amended in 1921 and 1923 gives the Indiana State Tax Commission jurisdiction over county and township bond issues. Under the provisions of the law as amended, notice of determination to issue bonds is given by the county commissioners subsequent to the award of a contract under the three-mile road law and the county unit road law, and within twenty-nine days from date of such notice, ten objecting taxpayers may file with the county audtor an objecting petition, it being mandatory on the county commissioners and the county auditor to submit such petition to the Indiana State Tax Commission for a review of the proposed bond issue and the commission's approval or disapproval of same.

As a result of this method of appeal to the Indiana State Tax Commission, the contractor is frequently without work for a period of from three to five months, and often when the work is advertised in the spring of the year, the greater part of the construction season has passed before the decision of the Indiana State Tax Commission has been made and, consequently, the contractor, with his equipment appropriated for a given project, is deprived of utilizing that season of the year most suitable to rapid progress and resultant profit.

The method of appeal likewise is unnecessarily costly to the taxpayer in that all engineering and legal work required by law is done, at the expense of the taxpayer, prior to the time notice is given of determination to issue bonds, and the project still remains subject to abandonment on disapproval of the Indiana State Tax Commission, if such be the commission's decision, and, furthermore, a delay resulting from such appeal deprives the taxpayer, not infrequently, from the use of an improved road, which in the absence of an appeal would under normal conditions be built in the same year of contract award.

To avoid unnecessary delay and in the interest of the taxpayer, as well as the contractor, we advocate a correction of the present method of appeal so as to have the proposed project appealed to the Indiana State Tax Commission, if the required number of taxpayers desire an appeal, before the work is advertised and on the engineer's estimate rather than after contract is awarded and on the proposed bond issue.

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Technical complications may arise in our effort to correct the present method of appeal, but with the co operation of the Indiana State Tax Commission (of which we have been assured) and others who are similarly interested in such correction, such complications will be met, and the correction so made as to conform to the law and to permit the Indiana State Tax Commission to handle such appeals with the least possible delay and, consequently, in the interest of the state at large.

The paramount advantage to the contractor in such correction in the method of appeal will be found in the fact that if such appeal be taken in advance of advertising the project, the present delay and doubt as to the contract being awarded will have been eliminated, and the successful contractor will be in a position to commence work immediately upon the sale of bonds, or as soon thereafter as may be deemed advisable.

Day Labor or Force Account Work

The evil of day labor or force account work is apparent to those who have been closely identified with public contract work, and, while Indiana has been comparatively free of such evil, it has been prevalent in many other states, and invariably has a tendency to demoralize the construction industry. I shall again call upon the Associated General Contractors of America to show the attitude of that organization toward day labor, as embodied in a resolution, adopted at their fifth annual meeting.

> "WHEREAS, There is manifest throughout the country a tendency among public officials to do public construction by the Day Labor Method, and
>
> WHEREAS, This method of expending public funds is generally recognized as being economically unsound as a general practice, in that it provides no foundation of responsibility and offers no assurance that such work will be of proper quality and performed for the amount of money voted or appropriated therefor, and
>
> WHEREAS, Our construction industry is full of notorious instances of the excessive cost of this construction method, and its encouragement to inefficiency, incompetence and sinister political influence, and of a strong tendency towards socialism; and
>
> WHEREAS, The constructors are especially fitted to interpret to the public this menace, and also lay upon us the responsibility of so doing; now therefore, be it
>
> RESOLVED, That the Associated General Contractors urge its membership throughout the country to accept as a major duty a campaign of publicity to show the results of the Day Labor method of doing public construction and to enter upon a vigorous and persistent effort to secure legislation which will require public bodies to do public construction by the sound method of firm contracts guaranteeing completion at a fixed price."

This resolution is self-explanatory and states in no indefinite terms the attitude of the construction industry toward day labor

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or force account work. I feel constrained, however, to state that contractors as such have no right to demand that the work be done by contract rather than by day labor. The contractor's major argument, and it is a sound one, is that in the great majority of cases he can save money for the public. This viewpoint is well stated in the following editorial which appeared in the Engineering News Record issue of January 1, 1925:

> "Contractors have no inalienable right to the construction work of the world. It has seemed often in the fractious discussions of day-labor construction which are currently being printed as if this truth were being forgotten—as if it were assumed that because the contractor is in the construction business he has sublime right to such construction as is being done. On sober thought no contractor believes this. If any contractor does believe it he is wrong because it is not so. If he talks as if he believes it he is foolish. The building public doesn't believe it and won't believe it. It believes that the contractor has a right only to that work which he can do as well as any other agency at less trouble and cost to the employer. And why should contractors want any greater consideration than this? They can save the owner from a multitude of worries and uncertainties inseparable from day-labor operations. They can do the work as well and in the vast majority of instances they can do it at less cost. There is much accumulated evidence in proof of all these facts and yet they have not been assembled anew in perhaps ten years. This should be done. A well presented brief is badly needed by contractors who have every so often to battle the hydra of force account construction of public works."

These then are some of the problems with which the contractor is confronted. As an association, we stand for a solution of these problems in the best interest of the public, for no other solution would be permanent or lasting. As agents of the public engaged in public work, contractors must keep in mind at all times the interest of the public. The Associated General Contractors of America is an organization representative of the nation's contractors and has for its motto, "Skill, integrity and responsbility." The Indiana Association of Highway and Municipal Contractors is a state organization whose objects are on an equally high plane and, therefore, equally commendable. The betterment of conditions in the construction industry characterizes our work, and we, therefore, feel that the whole scheme of organization effort, from the largest to the smallest unit, may be aptly summarized in stating that the contractors through organization advocate skill, integrity and responsibility in the construction of the nation's public work.

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SOME POINTERS FOR PUBLIC OFFICIALS HANDLING HIGHWAY WORK

By LAWRENCE F. ORR,
State Examiner, Indiana State Board of Accounts.

The results obtained by those who have services to perform for the public in the construction and maintenance of public highways are more directly observable by the taxpayers than any other public service. Those of you who have such duties to perform have an opportunity of producing something that will be well appreciated by the taxpayers, if you devote your energies and ability toward getting the best results with the money appropriated for that purpose.

It can not and will not be expected of you to go beyond the limits by which you are bound. If you contract beyond your means then you will be criticised for so doing, although you may attain good results thereby. You should keep within the appropriations provided and not attempt to exceed your authority although it may appear expedient to do so. Your limits have been prescribed both by statute and by those who have the authority to determine the means allotted for the work you have to do. Do not permit those who are to build or contract under your jurisdiction to deviate from the plans and specifications governing the work in hand. Our engineer examiners complain that they frequently find that plans and specifications are not carefully drawn and consequently contain some items which are in conflict. The engineer in preparing plans, profiles, and specifications, should exercise extreme care and see to it that such specifications provide exactly what is desired for that particular project. Local conditions will be encountered on most any road construction, requiring special treatment. The policy of taking a set of general specifications and setting them up to govern all of your road projects is a dangerous proceeding and will very likely lead to the making of changes after the contract has been awarded and the work started. The Supreme Court has ruled that all specifications must be sufficiently plain to describe thoroughly the work to be performed. If this is not done the whole project may be set aside as an illegal proceeding. A great deal of controversy will be avoided by detailing the work with sufficient clearness to admit of no misinterpretation before the contract is let.

Duties of Commissioners, Inspector and Engineer

It is the duty of the Commissioners to go over the plans, profiles and specifications with the engineer before advertising

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the work and eliminate all questionable or debatable items. All bidders should be compelled to bid exactly the same kind, quality and quantity of work and material. The legality of substantial changes made after the letting of a contract is seriously questioned, and in most cases will lead to trouble for both the commissioners and the contractor. Court rulings set out in no uncertain language that unless the work is done in substantial compliance with the plans and specifications, it is not a fulfillment of the contract, even though the work as performed is better and more costly than that which is specified. **Specify what you want and then see that you get it.**

The inspector or superintendent appointed by the Board of Commissioners to supervise the construction of a new road should be a man of intelligence and experience. His position is one of considerable responsibility. Frequently he must decide without delay upon a question of the intent of the specifications and he should be qualified to act with firmness and fairness. It is a mistake to clothe an irresponsible man with the authority that goes with this position.

The engineer should give close attention to the road under construction as the proper performance of the contract rests very largely on him. He should allow the contractor no estimate for work in place until he has satisfied himself that the work and material are actually on the job and that they are the kind specified. The commissioners should also satisfy themselves that they are not making an allowance in excess of the proper amount, and under the provisions of the statutes enough should be retained to take care of any labor and material claims which may be filed against the contractor. A construction bond should be drawn in such a manner that it will protect the county against defects in the road during the guaranteed period.

If it should be found to be absolutely necessary to depart from the original plans and specifications or make some changes after work has been started, the same should be set out in detail on the record book of the commissioners and written authority approved by the engineer should be given the contractor. Additions or deductions must be agreed upon between the board and the contractor before same are authorized and same should be made a matter of record. The records concerning the construction of a new road must be made full and complete because if our examiners are called upon to make an examination of the road, they must necessarily go into every detail and report conditions just as they find them. If the records are incomplete the examination may lead to a situation embarrassing to those responsible for the omissions.

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Limitations of State Board of Accounts

The State Board of Accounts is authorized to make examinations and investigations of contracts for public work under the provisions of the Acts of 1923. Before such examinations may be made, a petition therefore must be filed with the State Examiner, alleging that the contractor has failed to comply with the plans and specifications and that local relief has not and can not be obtained. The petition must be signed by at least twenty-five taxpayers who are directly interested in the improvement named.

Neither the State Examiner, Deputy Examiners, nor the Field Examiners are given any authority whatever to supervise the construction of such work or to prepare plans and specifications therefor. We are sometimes called upon to do this kind of work, but we must necessarily refuse, for reasons stated and further for the reason that as an examining department, we would be in an embarrassing position were we called upon to examine our own work.

Financing Highway Construction

In the matter of highway construction, I desire at this point to offer some information as to the provisions of the statutes pertaining to certain financial phases of such construction.

In the matter of advancing from county fund per diem of engineer and his assistants—if the improvement is under the County Unit Road Law, there would be no need of refund to be made to county revenue in case bonds do not sell, as the expense pertains to the whole county as a unit.

If the bonds do not sell for three mile gravel road law construction, and moneys have been advanced, same should be repaid to county revenue from the proceeds of a tax levy against the township or townships wherein the improvement was petitioned for.

In case of highway improvement under the inspection of the State Highway Commission, no claim can be legally allowed except with the approval of the inspector representing said commission.

County Commissioners are entitled to reinbursement for their actual expenses in and about the construction of highways under the County Unit Road Law and Three Mile Gravel Road Law, but they are not entitled to payment for services in connection therewith.

The surplus in the several gravel road bond funds in the township shall be transferred to a "general gravel road by taxation fund," which fund shall be used to liquidate the indebtedness

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of any free gravel road in such township for which the bond issue may have been insufficient. If a surplus still remains in the fund, such surplus should be applied to the payment of the gravel road bonds of the township.

Bonds shall be sold in sufficient amount to pay all preliminary expenses and costs of construction, including the per diem of engineer and superintendent of construction.

The County Unit Road Law provides that the bond issue shall provide for a sufficient sum in addition to other expenses to pay for any extras or changes not contemplated in the original plans, specifications and contract, which the board shall deem necessary, not to exceed three per cent of the contract price.

No part of the bond redemption fund can be used to pay a deficiency in the construction fund.

There are many other points that could be brought out in relation to road construction work, but I feel that I should proceed now with matters pertaining to highway repairs and maintenance.

Laws Pertaining to Highway Financing and Accounting

There are many statutes relating to maintenance and repair of highway. At this point, however, I wish to explain some of the essential provisions of the law in so far as they pertain to financial and accounting provisions.

The proceeds of the gasoline tax distribution to counties under the provisions of the statutes:

> "Shall constitute a special fund for construction, maintenance or repair of any public highway in the county."

The statute is clear in the providing for a "special fund" and therefore, the proceeds of such tax should be so carried and not placed in the free gravel road repair fund.

The gravel road repair fund can only be used for repair of free gravel roads while the special fund from the gasoline tax distribution may be used either for repair maintenance or construction.

No debts may be created against the gravel road repair fund except the money is on hand, or the debts be contracted against an existing levy in anticipation of its collection. Incurring of overdrafts in the gravel road repair fund as well as in any other fund, is illegal.

Claims against the gravel road repair fund must have the approval of the highway superintendent before the Board of County Commissioners may allow such claims.

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Publication of allowances on reports filed by assistant superintendents should show the total amounts paid to each laborer therein named.

Claims of material firms should be filed directly with the auditor, and allowed to the claimant and not to the assistant superintendent.

Any repairs made by the County Highway Superintendent upon a road, must be paid for from the gravel road repair fund, if the road has been taken over by the County Commissioners.

Receipts for payments made by assistant superintendents must be filed with the county auditor, to show that payments have been properly distributed by the assistant superintendent.

Aside from the requirements of the statutes which I have summarized herein there are many other ideas which are prompted by a desire to attain the best results from an economical and businesslike administration of your various offices. For example, it is very important in road work to determine the actual cost of placing material on roads and keep this data on file for reference. If this were done, I believe many instances would be found in which the cost, if known beforehand, would be considered prohibitive. Statistical data of this kind would be of great value in determining the cost of work to be done and in arranging appropriations and fixing levys. You should keep your material and labor costs on each project in such a way that they will be serviceable in estimating future work.

Our department is also recommending that all officials who have charge of any public property should keep a complete inventory of same. The total expense of county government when considered merely as an expense, oftentimes seems large, but if some thing tangible can be shown for such expenditures, or a part of it, in the way of machinery, equipment, tools, supplies on hand and buildings and land purchased we will then have something to show for the money so expended.

The keeping of such an inventory we regard as good business, and we regret to state that such a method has not been pursued to any extent in the state. The Department of Conservation, where a complete inventory is kept, is the one exception and most surprising results are evident.

In conclusion, I want to say just a few words concerning the State Board of Accounts. Some erroneous impressions have gone abroad concerning the activities of this department, some of which are not only erroneous but unfair. Like yourselves, we who have the administering of the Public Accounting Law are governed by statute, and we do not go any further in our examinations than the law requires of us. Sometimes our examiners are compelled to report things which some people do

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not like. This is not a pleasure to the examiners, but the statutes place responsibilities upon us which we must meet, and we do meet them fairly and squarely. Regardless of the consequences, our reports must speak the truth and show the facts as they are found to exist.

The law places the same authority with the department as to examinations of state offices and departments that it does in the examination of county, township and other public offices.

An office or department in the State House is not entitled to any more privileges in an examination of its accounts and affairs than the smallest town or township in the state.

Our examinations will be made without fear or favor and we will carry out our duties as provided by law.

During my administration as State Examiner I have endeavored to make the department helpful to all public officials and I invite you to send your problems and questions to me. We extend to you our services in the spirit of co-operation and assistance to the end that we may all serve to the best of our abilities in the interest of efficient, economical and honest government.

THE RESURFACING OF BADLY WORN CITY PAVEMENTS

By R. H. Simpson, Chief Engineer,
Dept. of Public Service, Division of Engineering and Construction, Columbus, Ohio.

The resurfacing of badly worn city pavements is a subject that is receiving considerable attention at the present time. The large increase in motor traffic has brought about a demand for smooth roadways, and many cities are attempting to transform their old pavements into boulevards by the use of some type of bituminous surface. Most of our highway engineers have also recognized the economy of salvaging whatever value there is in their old roads, and are resurfacing gravel and macadam roads with asphalt or other bituminous material. The increase in the construction of this type of pavement is no doubt due to the fact that the financing of a paving program, in most communities, is becoming a serious problem, and any saving that can be made in construction cost, which does not lower the value of the service rendered by a pavement, is certainly justified. In some cities this work is being done by the application of a thin layer of asphalt, having a thickness of one-half or three-quarters of an inch, and frequently this is feathered out to zero at the curb and

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at the rail of a street railway track. Such construction is no doubt justified as a temporary measure, but in this discussion I will ask you to keep in mind that resurfacing means the laying of a high type of asphalt surface on an old pavement, the latter being considered as a foundation for the new surface.

Through the co-operative efforts of all agencies engaged in the work, the science of road building has made greater strides during the past quarter century than for many centuries past. The industry is growing at a tremendous rate. We are now spending a billion dollars a year on roads and pavements. We, as engineers, have been so busy planning and supervising the construction of this vast volume of work, that I wonder whether we have taken enough time to investigate the work done, in the past, with the idea of utilizing in our present day practice, the experience gained from past performance.

Many cities in the United States have pavements that have been in service for a quarter of a century, or more, and it seems to me that if these pavements were studied with some care we would be able to draw some conclusions that would help, materially, in the design and construction of roads and pavements. I am not unmindful of the fact that many city pavements constructed in the past have illustrated how not to build rather than how to build, so we can learn from our failures as well as from our successes.

City pavements have not only been subected to traffic but to the heat and rain of many summers and the snow and ice of many winters, and it is the action of traffic combined with these destructive agencies that more often show up the defects in pavements or cause failures in them than the traffic alone. While many of our old city pavements were designed for traffic conditions as they existed twenty-five or thirty years ago, it is a remarkable fact that some of them are in good condition today and are carrying a traffic never dreamed of at the time they were built. From the experience gained during the past half century, municipal engineers have generally recognized the three fundamental requirements of a properly constructed high class pavement to be:

1st. A stable, well drained sub-base.

2nd. A firm foundation, strong enough to carry the loads to which it will be subected.

3rd. A smooth wearing surface to withstand the abrasion of traffic and protect the base and sub-base from the action of the elements.

It is pretty well recognized that the sub-base and foundation of a street or road should be constructed in such a way as to be a permanent investment but that the wearing surface of necessity

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must be repaired from time to time, and may, ultimately, have to be entirely renewed.

In the resurfacing which I will describe to you these fundamentals were kept in mind, as resurfacing in Columbus has only been attempted when the condition of the old pavement fulfilled the requirements for base and sub-base.

Methods Used in Columbus

We now proceed to describe the methods used in resurfacing old pavements in Columbus, Ohio; to tell you under what conditions resurfacing as a permanent improvement is justified; to give you the results obtained in terms of the cost of maintenance, and finally to compare these maintenance costs with that of the ordinary construction of high grade pavements using a concrete base.

There are four types of old pavements that have been resurfaced in Columbus, namely, brick, boulders, stone block and macadam. Of 195,110 square yards of this type of construction about 72 per cent of the work has been on brick, about 20 per cent on boulders and 8 per cent on macadam and stone block. In general it may be said that the results from stone block and brick have been uniformly successful and that in the case of the boulder pavements the results have been generally successful. The resurfacing over macadam has been of such recent date, the oldest pavement having been laid in 1922, that no general conclusion as to the merits of this work can, as yet, be stated.

The oldest paved roadway in the city of Columbus is Bryden Road, from Parsons Avenue to Twenty-second Street. It is a street with a forty foot roadway, and carries a large volume of traffic, from eight thousand to ten thousand vehicles daily. It is a sheet asphalt pavement laid in 1888 over boulders, and is, therefore, 36 years old. We have no record as to when the original boulder pavement was laid, but it consisted of a foundation of about eight or ten inches of crushed stone, the boulders being imbedded in sand on top of this base. At the time the asphalt resurface was placed on this roadway it was thought necessary to coat the boulders with a bituminous material so that the asphalt would adhere better to the surface. Therefore, cold tar pitch was sprinkled over the boulders before laying the asphalt. The asphalt was then laid without any binder, in the same manner as sheet asphalt is laid at the present time, it being dumped on the roadway and shoveled to place and raked to the proper thickness and then rolled. Two or three years later several other streets were laid in a similar manner, and, with one or two exceptions, the pavements are smooth and giving excellent service today. In 1912 another old pavement of this

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type was resurfaced, but in this case a binder course was used and the pavement laid in the same manner as a sheet asphalt paving. One of the streets resurfaced over boulders in 1891 is on our program for reconstruction this year. The sub-base conditions on this street are not first class and the construction of a sewer, some years ago, added to the sub-base defects. Another pavement laid the same year has shown rather high maintenance, due, partially, to frost action. The pavement on Bryden Road, however, is in very good condition today as may be observed by Fig. 1.



Fig. 1. Bryden Road, a boulder pavement, resurfaced with asphalt in 1888.

Resurfacing Old Brick Pavements

The resurfacing over old brick pavements has been done in more recent years, and we have definite information as to the details of the work and the construction method. Practically all of these old brick pavements were originally constructed between the years 1888 and 1892. They were laid on a macadam base, averaging about ten inches in thickness, which consisted of crushed limestone, such as is available in Central Ohio, and water-bound with crushed stone screenings. After rolling, a two-inch cushion of sand was spread over this surface, on which the brick were laid and the joints filled, in most cases, with cold tar pitch. These old pavements have given good service, although there has been considerable repairs made on most of them and all had, for some years preceding resurfacing, a rough surface which did not meet the requirements of motor traffic.

All of the resurfacing over brick has been done only after a careful investigation of the sub-grade conditions, as evidenced by the condition of the paving and the curbing. In some cases

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where there was some question about the condition of the foundation, or the sub-base, actual excavation was made to determine, definitely, these conditions. If it was found that the curbing had become displaced by frost action, or that the brick in the surface had, in places, become displaced, from a similar or other cause, we would naturally conclude that there was an unsatisfactory sub-base condition or a weakness in the foundation, or both, which, if extended over a considerable area of the improvement, would make resurfacing impracticable. The best time to discover a weakness in a pavement is in the spring when the frost is coming out of the ground, and it has been our practice, for some years past, to observe our old pavements at this season, so that we may know of any weakness in sub-surface conditions which would make resurfacing unjustifiable. We have, in Columbus, some brick pavements laid on macadam bases, in which ground water comes to the surface in the spring, and it is not unusual to see sections of these pavements utterly destroyed by traffic, at such time, the brick being actually thrown out of position or asphalt disintegrated and broken up by the traffic. Clearly, it would be a waste of money to attempt resurfacing under such conditions.

Rules Governing Resurfacing

In general it may be said that any pavement that has retained its general shape and contour for a period of ten or twelve years shows evidence of a satisfactory sub-base and foundation and that such a pavement may be resurfaced with a reasonable expectation of securing satisfactory results.

In preparing plans for resurfacing of any pavement it has been our practice to take cross sections of same at frequent intervals, which are platted on cross section paper to any convenient scale. From these sections a new crown for the proposed surface is worked out which gives the required minimum thickness desired for the new surface, or 1½ inch binder, 1½ inch top. On account of the worn condition of the old pavement, these sections will usually disclose the fact that at certain points the old surface must be built up to form a satisfactory crown, and where this condition is such as to require a thickness of three or four inches of binder, it has been our practice to place the binder in two operations; that is the low sections of the street are first brought up, with binder, to a crown three inches below that desired for the finished work, and then the surface put on in the usual manner.

If the depth of the gutter in the old pavement cannot be reduced, safely, it has been our practice to take up a strip of the paving four or five feet in width, and either lay a concrete foundation at a lower grade, over which the asphalt surface may be laid,

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or to lay a brick gutter that will give the proper depth at the curbing and a shoulder three inches deep against which to lay the asphalt. In this connection I might say that in sections of the city where there is considerable parking of automobiles, it is our practice, both in resurfacing and in the construction of new asphalt pavements, to lay a six foot strip of brick or granite block paving next to the curb, as a parking strip for automobiles. Fig. 2 shows a brick surface prepared to receive the asphalt top.



Fig. 2. An old brick pavement prepared to receive the asphalt top.

An extremely important feature in connection with resurfacing is the laying of drain tile along the curb on each side, and at other points if necessary, in order to insure a properly drained sub-base. We have used drain tile on all of our street construction in the past twenty-five years, and in resurfacing, where tile was not used, originally, we lay a four inch farm tile twenty-four inches below the surface of the paving, just in front of the curb line, with outlet at catch basins or sewer manhole.

In many cases we have found it desirable to reset and recut the curbing in connection with resurfacing, practically all of the curbing used in Columbus being Ohio sandstone. This is not absolutely necessary unless it has been forced out of position by frost action, but it improves the appearance of the improvement and the cost is only a small percentage of the total. Fig. 3 shows a typical section of this construction.

Detailed Resurfacing Operations

Our contracts for this kind of work are all let on a unit price basis, that is a square yard price for the surface, which includes 1½ inch binder and 1½ inch top, and a cubic yard price

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Fig. 3. Showing curb alteration necessitated by re-surfacing.

for additional binder. The first step in the construction of such an improvement is to excavate for the strip along the curb, lay the drain tile, reset the curb, if necessary, and lay the foundation strip along the curb, including the brick surface, if brick is used. The old pavement is then thoroughly cleaned with the use of water from a fire hose and men follow along behind with push brooms, sweeping the surface thoroughly to insure the removal of all dirt and foreign substances from the surface of the brick and the joints. After the pavement is thoroughly cleaned and dry, it is then ready for an application of the extra binder to bring the surface to the proper crown. When this is done the regular binder course, and the top course is laid in the same manner as the laying of a regular sheet of asphalt surface.



Fig. 4. Relaid brick at street intersection to provide shoulder for re-surfacing.

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At intersecting streets it is necessary to relay a portion of the pavement on such street in order to meet the grade of the new work. If this be an asphalt pavement a portion of the old surface can be heated and removed and new top added, building it up to meet the new crown. If it is a brick or block pavement it is best to relay a number of rows of the brick or block at the proper grade to form a shoulder for the asphalt. This detail is shown in Fig. 4.

The resurfacing over stone block is done about the same manner as over brick, the proper crown being mapped out and the surface laid as described above.

The first macadam pavement resurfacing was done in 1922 and the second in 1923, these two being the only pavements of this type resurfaced in Columbus. Both of these pavements had been built for twenty years, or more, with brick gutters along the curb, and the old curbing, brick gutters and macadam had shown evidence of satisfactory sub-grade conditions. The macadam had a thickness of fourteen inches. This surface was scarified to a depth of three inches and the material removed, after which the surface was rolled to a grade that would permit of the laying of three inches of asphalt and meet the shoulder of the brick gutter.

As stated before it is too early to form an opinion as to results of this work, as my experience shows that it takes from ten to twelve years of service to demonstrate whether or not a particular type of pavement is a success, and I will give you, later, some evidence in support of this conclusion.

Streets Containing Car Tracks

The problem of resurfacing a street containing car tracks is one that is rather difficult of solution, unless the tracks are reconstructed. We have attempted this on one street only, a main thoroughfare on which the maintenance cost had been very heavy for several years, and on which it was the desire to improve the surface without the expense of reconstruction. This work was done by city forces out of funds appropriated from maintenance, and if the new surface will last seven years, the cost of the work will not be in excess of seven years' ordinary maintenance.

In this case a strip of brick about twelve inches wide along the outer rails of the car tracks was relaid at such a grade as to give a shoulder against which to lay the asphalt, and at the curb the thickness of the resurfacing material was reduced to one inch in order to give a proper depth of gutter. Asphaltic concrete was used on this work except for a distance of about 2,000 feet on one side of the street where Kentucky rock asphalt was used in

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order to try out this material for this character of work. As an experiment, there was also laid for a short distance a manufactured asphaltic material known as cold laid asphaltic concrete.

This material was all laid without a binder course, and to a depth of two inches, except at the rail and curb where it was reduced to one inch. The work was done during the fall of 1924 and while it has promise of giving satisfactory results it will take some years to demonstrate whether this cheaper type of construction is justified.

Costs

The cost of resurfacing will vary in different communities, depending on the cost of labor and material. In Columbus, when done by contract, the work costs, where binder is used, from $1.65 to 1.75 per square yard, and where the curb is not reset, or new gutter laid, it has been done for from 50 per cent to 60 per cent of what new construction costs, depending on the amount of additional binder required to provide a proper crown for the street. When new gutters are laid and the curbing reset, the cost amounts to from 65 per cent to 75 per cent of the cost of new work, depending on the type of paving used for the gutters.

The maintenance cost of city pavements is a subject that has not, in the past, been given as careful investigation as is warranted by its importance. However, it is now being recognized that the maintenance of city pavements is a very important part of city service and is receiving more consideration in the financial program of progressive cities. In Columbus we have been able, however, especially in later years, to secure funds enough to maintain our pavements in a fairly satisfactory manner, judging by the very few complaints relative to them registered by our citizens; so that we will not be making a violent assumption when we say that the pavement, on which maintenance costs are given herein, are in good condition today.

In preparing some maintenance data on our resurfaced work in connection with this discussion, I thought it would be of interest to give you a comparison of such costs with the maintenance cost on the ordinary type of sheet asphalt construction. Before doing so, however, it will be necessary to describe, briefly, how the repairs are made and cost data compiled. Prior to 1907 our asphalt repairs were done by contract on a unit price basis; the area of the surfaces repaired being carefully kept and payments made in accordance therewith. In 1907 the city installed an asphalt plant of 1,000 yard capacity, and since that time the repair work has been done by city forces. We have continued, however, to keep the same data as when the work was done by contract; viz: the repaired area and the cost. To arrive at the

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cost we figure the entire cost of the season's work, including labor, material, supplies, a charge for use of plant, etc., and divide this by the total yardage of the repaired area, which gives a unit cost to be applied to each street.

During the past three years I have been compiling these figures for all of our pavements, some 6,000,000 square yards, and 1,300 improvements, with the idea of having a complete service record of each particular improvement, and we have just completed this work for our asphalt pavements, involving some 300 improvements and 1,770,000 square yards. In compiling these figures it has been my aim to show each year for each improvement:

1st. The area of the improvement.
2nd. The area repaired.
3rd. The cost of the repair.
4th. The cost per yard of total area.
5th. The average cost per yard per year.

This last figure is really the service test of a pavement. It gives the average yearly cost over any period of years. As a pavement becomes older it will cost more per year to maintain it, and unless we know the age the maintenance cost does not mean much. The average cost per yard, per year, is obtained by dividing the total cost of repairs up to a given date by the total area of the improvement in yards and this quotient divided by the age of the improvement. Thus an improvement having an area of 10,000 square yards and being 20 years old, on which the total maintenance cost during the entire 20 year period was $5,000, would have an average maintenance cost per yard per year of 2½ cents. The maintenance on the resurfaced work over the old boulder pavements, the oldest of which was paved in 1888, averages a little over 3 cents per yard per year for the 36 year period. The resurfacing over the brick pavements, of which there are 24 improvements, has been done since 1912, the aggregate yardage of this work being 149,889 yards. The average age of these pavements is 5.6 years, the oldest being 12 years. The total maintenance on these 24 improvements, since they were constructed, amounts to $719 or .00086 cents per yard per year. In other words, if the combined yardage of these pavements was considered as a highway 18 feet in width this highway would be 14.2 miles in length and would have cost about $8 per mile per year for maintenance.

Critical Period in Life of Pavement

Fig. 5 gives, graphically, the maintenance figures for asphalt pavements, the age being shown by the horizontal ordinate and the cost in cents per yard per year by the vertical. The heavy

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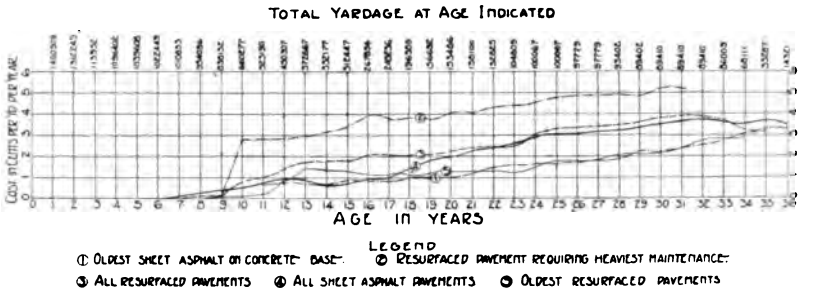

TOTAL YARDAGE AT AGE INDICATED
AGE IN YEARS
LEGEND
① OLDEST SHEET ASPHALT ON CONCRETE BASE
② RESURFACED PAVEMENT REQUIRING HEAVIEST MAINTENANCE
③ ALL RESURFACED PAVEMENTS
④ ALL SHEET ASPHALT PAVEMENTS
⑤ OLDEST RESURFACED PAVEMENTS

Fig. 5. Maintenance costs on asphalt pavements.

dash line shows the aggregate of all resurfaced pavements at the various ages. These figures have been obtained by adding together the maintenance cost for each improvement at a certain age, regardless, of course, as to when the improvement was made, the points for the curve being obtained by dividing the total cost up to a given year by the total yardage of pavements that were in service on that year and then this quotient divided by the number of years. The heavy dotted line shows the expenditure for all sheet asphalt pavements. The solid fine line shows our oldest resurfaced pavement which as you will note has a remarkable record. In order to make a comparison I have shown a broken line showing the oldest sheet asphalt pavement on a concrete base. The resurfaced pavement which has required the most maintenance is shown as a broken line above all other curves, and I have shown this in order to give you an idea of the range in maintenance cost as well as the average. From this chart a line could easily be plotted from which the maintenance cost for asphalt pavements could be estimated at any age. You will note that these curves all take a decided rise somewhere between the 10th and 12th year, indicating a comparatively heavy maintenance cost at this time. Most of them flatten out after that period and in case of some of them the cost during the next few succeeding years is less than at that period. This fact seemed rather startling to me, and in order to determine, if possible, the reason for heavy maintenance at this age period, I made some studies of several pavements of various types. Our earlier asphalt pavements were constructed under a ten year guarantee, and the records seemed to show that a few of them had been neglected for two years or more prior to the expiration of this guarantee, which would naturally increase the cost at that time; but for the past 15 years our guarantee period has been 5 years, so that the heavy maintenance on all of the pavements can not be attributed to neglect immediately prior to the expiration of the guarantee. In fact we have a large yardage that has passed the 10th year without requiring any main-

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tenance. On the other hand I found that we have a number of pavements carrying heavy traffic on which the records seem to confirm the theory that the period of heavy maintenance is when they are from 10 to 12 years of age. To illustrate, an important street leading to the north was paved with asphalt in 1911. The present traffic on this street is about 12,000 vehicles daily. It passed the five year guarantee period without requiring maintenance. At the age of 8 years the cost per yard per year was $.008; at 10 years, $.045; at 12 years, $.07.

We have another main thoroughfare leading to the north in Columbus that was constructed in 1908. This was a brick pavement on a concrete base with a tar filler. It receives very heavy traffic, a count indicating that a traffic of approximately 16,000 vehicles use this roadway per day. During the years 1921, 22 and 23 this pavement was entirely resurfaced because the brick were so badly worn and broken as to make the street unfit for modern traffic conditions.

Another street 50 feet in width, carrying approximately the same amount of traffic, was constructed in 1911 of brick with a grout filler. This street was in excellent condition for a 10 year period but during the last 2 or 3 years we have been obliged to give it considerable maintenance, and the maintenance cost up to date has averaged about 4½ cents per yard per year, practically all of which has been done within the last three years.

Probably the most striking example is afforded by a sheet asphalt pavement laid on a portion of a thoroughfare leading to the east, a street which carries about 12,000 vehicles daily at the present time. This was constructed in 1890. In 1901 this roadway was resurfaced and in 1913 it was resurfaced for the second time. In 1924 we were obliged to reconstruct this pavement due to the fact that during the spring of 1924 ground water came to the surface and destroyed such large areas that it was not considered wise to attempt any repairs. This failure was due to an improperly drained sub-base and a weak foundation, but the point to which I wish to call your attention is the fact that in spite of this bad condition this pavement gave satisfactory service from 11 to 12 years after each repair.

In addition to the above examples as bearing on this heavy maintenance period, I wish to call your attention to an article by Professor French, of Mt. Gill University, published about 2 years ago, giving the results of an inspection of about 340 miles of concrete roads in northern United States and Canada. Without going into details I will say that his conclusions were that on heavy traffic roads the condition of these concrete pavements was such as to need resurfacing at the age of 9 years and on the light traffic roads at the age of 13 years.

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Based on our records there seems to be ample evidence to show that when a pavement has required heavy maintenance it has been during the 10th to 12th year period after construction, but I do not wish to be understood that such conditions are common to all pavements.

For instance, of the total yardage of our asphalt streets that are 10 years old, or more, 60 per cent of their area or 396,293 square yards have reached that age without requiring any maintenance, 40 per cent have reached the age of 12 years without maintenance, 16 per cent 15 years, and we have four streets with a total area of 11,443 yards which have been in service 18 years without maintenance expense. However, as a result of these studies and supported somewhat by Professor French's investigation, it would appear that there is a critical period in the life of all pavements, and that this period is from the 10th to the 12th year after construction. Pavements may pass this period successfully by reason of favorable traffic and other conditions, and they may develop a weakness before this time by reason of abnormal conditions, but the evidence seems to show that serious defects, either in sub-base, foundation, or wearing surface, do not necessarily develop until this critical period, and we should hesitate, therefore, to draw any definite conclusion as to the merits of a pavement until such pavement, after 12 years' service, with moderate maintenance, is found to be in satisfactory condition.

While the diagram indicates that from the 10th to the 20th year after construction, the maintenance on resurfaced work has been greater than for asphalt pavements on a concrete base, beyond the 20th year the maintenance is substantially the same, and we can, therefore, conclude that the results from the resurfaced work as measured by maintenance cost, are nearly equal, if not entirely so, to the results obtained from other construction. In fact a comparison of the resurfacing over old brick pavements which were completed 12 years ago, are now in as satisfactory a condition and have received no greater maintenance than other work constructed at the same time.

These results are due, largely, to the care used in selecting for resurfacing only those streets which, after long service, have shown evidence of satisfactory sub-base conditions, and it is only by a study of these conditions, and correcting them if unfavorable, that a successful pavement of any type can be constructed.

In conclusion let me suggest that the pioneer days of constructing modern pavements is past, and in the future the problem will be studied in the light of experience gained from past performance. For I believe that from a study of the behavior of our pavements under actual traffic and climatic conditions, much can be gained to aid us in solving our paving problem.

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SAFETY ON THE HIGHWAYS

By Prof. W. K. Hatt,
Head, School of Civil Engineering, Purdue University.

The construction industry amounts to an output of six billion dollars a year in the United States, that is fourteen per cent of the national income. Of this, one billion is put into highways in one form or another.

We are only at the beginning of the highway industry, however. The farther we go the more important the operation of the highways becomes. Operation involves a most important element—the maintenance of roads. State Highway Engineers are alive to the importance and complexity of the problems of maintenance. Our county highway superintendents have no less interest in this very difficult task of maintaining roads against the traffic of motor vehicles. They, as well as the state engineers, are gravely concerned with the **safety** of the roads under their charge.

Accidents are increasing rapidly with the seventeen million motor vehicles on the roads of the United States. The use of the highways under certain critical conditions of traffic is now a hazardous occupation.

Accidents on streets and highways increased fourteen per cent last year, whereas accidents in other classes decreased. Twenty-two thousand six hundred people were killed on the streets and highways of the United States last year; eighty per cent of these were killed either in driving automobiles or getting in the way of automobiles. Half of these accidents were due to recklessness and carelessness. We may contrast this figure of twenty-two thousand six hundred with the fact that in the four years of the Civil War one hundred and ten thousand Union soldiers were killed in battle or died of wounds. It has been said that if the highway accidents keep on at their present rate, we will approach in four years the casualties of the Civil War.

There are four persons concerned in avoiding accidents—first, the engineers who build and maintain the highways; second, the manufacturers who supply the automobiles; third, the man who drives the automobile; and fourth, the pedestrian who walks the roads. Each of these four must look ahead and do his best to avoid accidents. We must not only desire safety, but we must also **study** the cause of accidents in a scientific way, and then **create** the conditions which promote safety.

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The county highway superintendents have no way of preventing the reckless and careless person from driving an automobile. It is up to the state authorities to license only competent persons after an examination as to their fitness. The county highway superintendents, however, can make the roads reasonably safe for the reasonable driver.

It is this growth of accidents on the highways that led Mr. Herbert Hoover, Secretary of Commerce of the United States, to call a National Conference on Street and Highway Safety in Washington, D. C. To this conference were gathered various persons interested in building highways, in constructing automobiles, in planning cities, in education in the public schools in order to study the reasons why accidents occur and the best means of preventing them.

There is a lot of misinformation and erroneous views of the cause of highway accidents. Many unexpected facts result from a careful study. For instance, it is found by actual observation that more accidents occur on the straight part of a road than on curved parts. This is contrary to the usual view. The fact that there are more accidents on the straight roads is explained by the extra precautions taken by the drivers in points of danger, like curved roads, whereas on the straight-a-way their attention is diverted and they become careless.

Another erroneous view is sometimes held that high speed is in itself a necessary cause of accidents. The fact is that one vehicle moving too slowly is likely to force other vehicles, which travel at a reasonable rate of speed, to pass it, and thus incur a danger on a two-track road.

The fact is that our highways are now becoming so crowded that speed is necessary if they are to discharge the traffic. Any piling up of traffic because of slow speed will increase accidents.

In other words, we are coming to the condition of a railway where traffic must be kept going over the tracks, and there must be all sorts of signs, signals and controlling devices. These traffic rules, these signs and signals are for the purpose of expediting traffic and not for slowing it.

To promote safety on the highways the roads should have a minimum width of 18 feet. The grades should not be too steep, not over six per cent. There must be a good clear vision ahead for at least three hundred feet. White streaks should be painted in the middle of paved roads at the top of hills and around curves so as to keep cars on their own paths of travel. The bottom of telegraph poles and other side projecting objects should be painted a light color. Signs should indicate steep grades, sharp curves, and railway crossings. Highways cannot be made "fool proof," but signs will warn the careful driver.

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The automobile builder must furnish good brakes which work when required and proper lights which will not drive the approaching vehicle off the road. He must limit the width of trucks so that they may be passed without danger.

The driver must see that his brakes are maintained in good condition, the whole car in good working order, and a wind shield wiper installed.

A pedestrian must obey traffic laws, must not do any "jay walking." When on the road at night the pedestrian should carry a lantern and keep on the left side of the road. For the pedestrian the engineer should provide a smooth path along the side of the road in the shape of a good shoulder to the road. As a fundamental rule, the driver of the automobile should yield to the pedestrian when their paths intersect. Only competent drivers, those without physical defects that interfere with safe operation, should be licensed, and reckless drivers deprived of their cars. The punishment of wilfully reckless drivers is seldom adequate. Somewhere carelessness becomes a crime.

The whole question of highway safety is one of the most vital questions before the public. It influences the layout of city streets and the work of city park commissioners. Final solution does not depend upon general opinions, but on scientific study of the causes and nature of accidents.

Systematic, thorough and continuous education of the public will lead to fewer accidents, as in fields of industrial accidents. Uniformity of laws in the several states will also promote safety.

In Indiana we have a large mileage of good roads, but much must yet be done to increase highway safety. Curves should be widened and banked, guard rails of substantial type should be erected on the shoulders of embankments, especially near curved roads approaching bridges where many people now run off the road at night. There are many narrow bridges in Indiana which should be changed to two line traffic bridges at least twenty-two feet wide between rails. Roadway shoulders should be kept in good condition. To the users of automobiles we must say, test your brakes, keep your wind shield clean, use your lights so as not to blind an on-coming car, keep your own side of the road, and be careful not to pass a car in front of you unless you have a sure right-of-way against an oncoming car. Lose a minute and save a life.

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SIGNS, GUARD RAILS AND RAILROAD CROSSINGS

By J. J. GRIFFITH,
Ex-Marion County Engineer.

"The Commissioner" said in an article, published in the November issue that the motorist must believe in signs in this day of rapid travel, otherwise he takes a chance, which often ends in the last chance he ever gets to take. Road signs are classed as necessities in these days of progress, for fast travel makes it imperative that traffic be safe at all stages. The need of marking roads with signs that even he who speeds may read, grows more imperative.

Various state highway commissions have taken the lead in doing everything possible for the safety of the motorist. The increase in travel accidents has caused the authorities to make even greater efforts towards eliminating travel dangers.

I want to see a law passed compelling the counties of the state to mark their roads so tourists can tell where they are going and also give them warning of the dangerous places along the roads. Road superintendents should make a special study of their counties, so as to learn what can be done towards making all dangerous places safe. It is important to warn of sharp curves or turns which occur suddenly after a long stretch of straight road. Such curves or turns are more dangerous than on a road that has many such curves, and as all turns and curves can not be avoided it is up to the motorist to believe in signs as he rides along.

There is one thing that I want to see removed from every road in the state, and that is all advertising signs. Such signs detract from the beauty of our roads and the scenery alongside. Removal of such obstructions will facilitate the maintenance of ditches and berms, and also will make the road safer by not interfering with the clear vision at railroad, traction line, and cross road intersections. Removal of these signs will make more effective the danger warning guides and other information signs. I am glad to see our State Highway Commission removing all advertising signs along state roads.

Every county in the state should adopt standardized signs, the same as used by the state, for the different states, with a few exceptions, are adopting practically the same signs used in Indiana. The different caution signs used by county or state are the school zone, cross road, side road, slow, oil, turn, curve, narrow bridge, narrow road, loose stone or gravel, through highway

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stop, city limits, no parking on traveled roads, speed 25 miles an hour, no dumping, not safe over 5 tons, and railroad signs.

The most important of all is the railroad sign, yet people pay little attention to it. The Delaware state highway department is using a combination warning sign and partial barrier, designed to induce caution on the part of automobile drivers. The combination signs and barriers are fixed 75 feet on both sides of tracks. This sign is set in the middle of the road. The barrier, or post, is about six feet high, with two cross arms on the top, one reading "Look Out For Train," and the other reading "Railroad Crossing." The roadway at this point is widened to provide space around the barriers to a width of ten feet on either side. For the protection of night drivers there is a flash light that flashes 45 times a minute. Below the flashing light is a red flex mirror, which reflects the light of approaching automobiles at night, and back of this sign, leading to the railroad, is black and white lattice work painted on the road. Thus there are five different warnings at this crossing: first, the bend in the road; second, the flashing light; third, the red reflection; fourth, the standard crossing signals at the top, and fifth, the black and white lattice work. Devices similar to these are being used in Nebraska on the Chicago & Northwestern Railroad. It will take crossing protection of this kind to stop the motorist who usually pays no attention to railroad crossings.

County roads should be marked with the names of the roads, the same as state roads are marked. Also, for night driving, cross roads, dangerous crossings and all bad places in all roads should be marked with red flex signs. These have been adopted by Marion county and a number of other counties in the state and are proving satisfactory.

The marking which has been the best investment Marion county has made was adopted last year. This is marking the road by either a white line down the center or by using emulsified asphalt and making a black line. The latter gives the best results and lasts longest. We have watched the heaviest travel on Northwestern Avenue or the Michigan Road leading out of Indianapolis, and also, on the Crawfordsville Road, and saw hundreds of machines passing over these roads, all keeping on the right of the center line and making the 18 and 20 foot roads safe to travel.

Guard Rails

There are very many different types of guard rails, some of which are built for looks, some because they are cheap, and others are built for real protection to the motorist. I have experimented with all kinds. I built the wooden guard rail, which

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was built for looks and served only as a warning. There were more people hurt by the wooden guard rail going through the car and wrecking the car than there would have been if there had been no rail at all. I have also had the post and cable type, which is being used in some of the states, but experience has taught me that the cable offers little visibility and has practically no elasticity.

As you know, it is not the policy of the Road School to boost any one product during the school, but as wire guard rail is now being made by several firms, it is a matter of general news to road builders and engineers that it is being found satisfactory as a protection at points of danger. Guard rails should be a real protection, as well as a warning of danger. This woven wire rail overcomes all objections in that it is painted white after galvanizing and, therefore, insures excellent visibility. The character of its weave makes it very elastic, and it stretches on impact to take up the force of the blow. Comparatively light machines at moderate speed break through the wooden rail or bound over the cable guard, while light or heavy cars are held on the road by the elastic wire guard with little injury to either car or passengers.

From the cost standpoint, figures show that the wooden and cable guards can be bought cheaper than the wire guard, but the installing costs are very much less with the latter, making the cost complete less than either of the former guards.

Railroad Crossings

The past year or two have witnessed many improvements in the type of railroad crossings and it would be difficult to name the many crossing materials that have been tried or are being used to determine their merits for this particular use. The materials offered include rubber brick, various bituminous bricks, concrete slabs, creosoted wooden blocks, creosoted edge set timber sections, iron plates, and the ordinary planking. I believe all these innovations should be welcomed by the engineers and authorities and the efforts towards improvement along this line should be encouraged. It certainly goes without saying that the worst part of our public highways is the general railroad crossing.

It will be generally conceded by all who are interested in the subject that the prime requisite for a highway crossing is that it should be smooth, reasonably hard and possess the ability to withstand vibration. Any discussion of the subject of railroad crossings must take into consideration several factors:

First and above everything else, the public demands a smooth surface road in order to cross railroad tracks.

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Second, a crossing must be built and maintained by the railroad for the benefit of the public. I think safety conditions for both the railroad and highway traffic demand this.

Third, a crossing cannot be designed as a permanent structure, for the reason that improvements must be made from time to time in the track.

Fourth, the material that possesses the most points of efficiency and economy is a debatable point among those who are authorities on the subject. However, it would seem that a crossing composed of edge set timbers made into slabs, creosoted, will very well meet the requirements. It is well known that the exposed edge of green timber will stand the wear and tear of traffic better than a flat, green surface. Also, that edge grained timbers, when properly assembled into slabs, will withstand vibration. Slabs manufactured from edge set timbers are comparatively non-warping and are smooth and flat. When manufactured from 2x4s or 2x6s, the slabs are sufficiently heavy to stay put, but are still light enough to be easily removed for repair to the track.

One important advantage of these timbers assembled into slabs is the fact that they may be turned over and the bottom side used. Timbers set on edge are not subject to the trouble of cracking and checking, as is usually the fault with block and plank crossings.

Another important advantage of this edge set timber crossing is the freedom from expansion troubles. That the edge set timber crossing is growing in favor is shown by an article in the "Railway Engineer and Maintenance" magazine of August, 1924. This article, by Mr. John Foley, Forester for the Pennsylvania Railway System, states that better results are to be expected from flat, green scantlings laid on the edges and bolted or nailed together than from flat, green planks laid on their sides. In the April issue of the same periodical is an article entitled, "Highway Crossings Designed on the Southern Pacific," which also concludes that a plank crossing made of edge grained timber is best.

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SURVEYS AND PLANS FOR COUNTY ROADS

By Don Heaton,
Benton County Surveyor.

Before discussing methods of making plans for county roads, I want to say a few words about the value of good road plans. After several years' experience I am firmly convinced that there is a very close relation between road plans and the taxpayer's pocketbook.

Most all of our county highways are built by contract. The value of any highway contract is in direct proportion to the value of the plans and specifications, for they are the part of the contract that sets out what is to be done and how it is to be done. If the plans are indefinite and do not clearly set forth the requirements and conditions for the construction of the improvement, the value of the contract to the taxing district that is paying for the road, is far below par.

If you have given this subject of plans for roads any observation or study, you will notice that there is a close relation between road plans and road contractors. Poor plans attract a poor class of bidders, and good plans attract a good class of bidders.

As a rule poor plans are more flexible and liable to substitution than good plans. The specifications accompanying poor plans are indefinite and very often some detail of the work might be built in two or three different ways and still be open to argument as to whether the work is performed in accordance with the plans and specifications.

The unscrupulous contractor who is in the habit of slighting work and interpreting indefinite provisions of the plans to his own benefit, enjoys arriving at a letting and finding a poor set of road plans. He is quick to see loop-holes and possibilities of inferior substitutions and makes his bid accordingly.

He has some right to assume that, if the plans are prepared in a slip-shod manner, that the construction will probably be handled in the same way. Good plans always command respect and inspire confidence.

The first class contractor who is in business to stay and who likes to leave a good record wherever he works, does not care for this kind of competition, and seeks localities where plans are prepared in such a manner that the hard working and conscientious bidder has a fair show.

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Surveys and Plans

In discussing methods for making plans and specifications for county roads, I have not taken up every detail of the work, but just enough of the essential operations to give a fair idea of what is required.

The survey is made for the purpose of getting information in the field and includes the accurate location of all physical and topographical features that may affect the improvement. Part of this information is obtained with instruments, such as the level, transit and tape, and part by personal observation.

The principal work to be accomplished in the survey is the location of the center line of the proposed road and the taking of levels to find the difference of elevation of points along and adjacent to this center line.

As a rule county roads in this county are located along section or fractional section lines. In making the survey no time should be spared in getting the center line of the proposed road properly located. This is the key-stone of the whole survey. Every thing else is built upon it. Personally, I spend three or four days or a week, if necessary, hunting corner stones and other monuments that determine the proper and legal location of the proposed improvement.

It is important that the plans be based upon the same center line as the one used in construction. Don't take cross sections from one center line and set slope stakes from another.

Very often there will be fences within the highway location that must be moved. The proper location of the center line at the start of the survey will save a lot of trouble and annoyance about property lines later on. If the line is established by existing corner stones and legal monuments there is seldom any complaint by the landowner when he is ordered to move his fence.

Once the ruling points on the center line are established the next work is to run the transit line, set station stakes, and take notes on topography far enough on each side of the center line to include all areas that will probably be affected by the improvement. Having located the ruling points on the line, the transit is set over the first hub stake, or corner stone and sighted to the next stake or corner stone on the line of the road. The bearing of this line is noted, also its deflection from an intersecting road at this point, if there happens to be one. Successive points on the center line at each station are now obtained by signals to the head flagman, who places his flag-pole at the proper points. If a cross section party is following the transit party it is common practice not to drive stakes every hundred feet, but to drive a small nail with a piece of red cloth attached

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to it, at each station on the center line. These are easily found by the level party, and save driving stakes until construction is started.

If the levels are to be taken at some later time, off-set stakes are set at such a distance from the center line that they will not be broken or disturbed by traffic on the road. On these stakes must be marked the station number and distance to the established center line.

After setting one-quarter or half mile of stakes the transit is moved up to the next hub stake, sighted to the point just left and then sighted upon the next corner stone or hub ahead. The deflection between these two lines is noted, also the bearing of the line, station number, and distance from the last set-up.

When the head flagman comes to a bridge he takes points on the line at each end of the span and notes in a note-book the station number of each end of the span, also distances from the center line of the road to the center line of the bridge. The location of all buildings along the road are obtained by measurement and the station number of all transverse fences, both property line and field fences, are noted. The direction and location of water-courses, both open and tile, are also noted on the transit book map.

After the transit line is run and topography taken, the cross section and center line levels are obtained. A cross section party usually consists of four men, namely, a leveller, rod-man and two chainmen. In doing this work, one chainman goes to the station stake and notes the distance marked upon the stake to the center line of the road as established by the transit party. Using this distance the zero end of the tape is placed on the center line and the tape stretched across one-half of the highway. With the tape in this position the rod-man gives the center line reading and then walks along the tape selecting points that will give a good representation of the ground surface. As the rod is held and read at each point the rod-man calls out the distance of each point from the center line for the leveller to place in the note-book. The tape is then stretched across the opposite half of the highway and the operations repeated.

Where the route of the road is over the location of an already established highway, it generally requires from seven to nine level readings to obtain a representative cross-section. On new location and fairly level ground this number will be considerably reduced.

Office Work

With the transit and level work completed the scene of operations is shifted to the office. Before starting the office work it is a good plan to decide upon the form and general make-

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up of the completed set of plans. Are you going to have a profile several feet long, or are you going to use small sheets of paper with several profile lines upon each sheet? Will the cross-section sheets and bridge plan sheets all be of the same size? These are some of the things you will have to decide upon. These questions are easily decided, if you use the sheets designed by the U. S. Bureau of Public Roads. These sheets are the plan-profile type and of a size that when bound together are portable and easily handled. The size of the border line on each sheet is 22x33½ inches. Thirty-two hundred feet of road can be placed on each sheet to a scale of one inch to one hundred feet.

In addition to plan and profile sheets the plan will contain a title sheet which should show a general layout of the improvement and immediate vicinity. Bridge drawings and cross sections are made upon sheets that conform to the size of the plan-profile sheets, and the whole bound together when finished.

In plotting the line there are two or three methods in common use. The most common is to plot the different tangents by means of a protractor and scale. Another method often used is the tangent method in which the line of each tangent is produced and offsets from this line computed.

The profile is plotted just below the plan. Stations are marked off on the horizontal line corresponding to the same stations upon the plan. The ground or surface line shown on the profile should represent the center line of the new improvement. The horizontal scale of the profile, usually one inch equals one hundred feet, is also used in making the plan. If the horizontal scale of the profile is one hundred feet to the inch, the vertical scale should be about ten feet to the inch.

In addition to the center line the profile should show the grade of the new road, together with elevations of grade points and elevations of grade of each one hundred feet. It should describe and give the elevation of all bench marks. The elevation of all drainage structures and the flow lines of all intersecting drains, either open or tile, should be shown on the profile.

A convenient scale for plotting cross-sections is one inch equals five feet. In plotting cross-sections the horizontal and vertical scales are the same.

With the plan, profile and cross-sections plotted, the next step is to establish the grade of the new road. Whenever possible, it is important that the grade of the road be so established that the amount of excavation and embankment will be about the same, without excessive and expensive haul. The most monotonous job, in my opinion, involved in preparing a set of road plans, is to establish a grade-line which will balance the volume of cut and fill, but I firmly believe that the extra work

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required in the office is fully justified by better construction and lower and more intelligent bidding. The operations are about as follows: Having decided upon the cross-section of the new road, a cardboard templet of this section is made to the same scale as that of the plotted cross-sections. A trial grade line, say 500 or 1,000 feet long, is established by inspection and the grade elevation at each station computed. These grade elevations are marked upon the cross-sections. The templet of the new roadway is then centered upon the cross-sections at the elevation of the new grade throughout the length of the trial grade line, and a pencil run around the templet to outline the proposed roadway. After this operation is completed, you have an outline of both the new road and the old road at each one hundred feet of the trial grade. Sometimes these two outlines will be very close together; at other times they will be widely separated, depending to what extent the new grade conforms to the existing grade. The space between these two outlines represents area for obtaining volume of cut or area for obtaining volume of fill. These areas are usually mixed at each station, part representing fill, and part representing cut.

The next step is to compute the area of the cut and fill sections. This can be done by dividing the irregular areas into regular geometrical forms, such as rectangles, triangles and trapezoids and computing the area of each small figure. A much faster method, and one that is usually within the required degree of accuracy, is to use a planimeter for obtaining the areas.

The areas of cut and fill are figured separately and the average end area for any station, multiplied by one hundred and divided by twenty-seven, gives the volume of cut or fill for that station in cubic yards. If the volume of cut and fill do not balance, a new trial grade is established and the operations repeated until the amount of excavation and embankment are about the same.

I have outlined in the foregoing paragraphs the essential operations involved in the preparation of a set of county road plans. Many of the details I have not attempted to discuss, such as location curves and vertical curves; also, shrinkage, bridge plans, etc.

It pays to spend considerable time in drafting, in lettering, and in making plans neat. There is nothing that improves a set of plans like good lettering. If you can not letter yourself, hire some one that can.

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PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE

Circulars

*CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

CIRCULAR No. 3. Hints on Automobile Maintenance, by H. A. Huebotter, 1924.

CIRCULAR No. 4. Operation of Three Phase Induction Motors Under Abnormal Supply Conditions, by D. D. Ewing and C. F. Bowman.

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Mimeographs

The following material has been issued in mimeograph form:

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STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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A City Planning Primer

G. E. LOMMEL
F. G. BATES

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BULLETIN NO. 11
ENGINEERING EXTENSION SERVICE

A City Planning Primer

BY

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PURDUE UNIVERSITY
LAFAYETTE, INDIANA
JULY, 1925

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BEFORE



AFTER

The Thieme Improvement at Ft. Wayne, carried out several years before the passage of the Indiana City Planning Law.

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FOREWORD

At the January, 1925, meeting of the Executive Committee of the Indiana City Planning Association, the problem of placing authoritative information on the subject of city planning in the hands of interested citizens was discussed at some length. The result of that discussion was the formation of a publicity committee consisting of Professor Frank G. Bates of Indiana University and Professor G. E. Lommel of Purdue University.

This committee was charged with the responsibility of developing a short pamphlet dealing with the elements of city planning which would be directly applicable to Indiana conditions. The discussion further developed the fact that a real need for this primer exists in the high schools of the state as an aid in the study of city planning in the civics courses.

With this in mind, the committee carefully worked out their assignment and the text matter was presented at the third annual city planning conference which was held at Evansville on April 9th and 10th.

The Engineering Extension Department at Purdue then decided to print and distribute the primer as an Engineering Extension Bulletin.

Acknowledgment is here given to the Ft. Wayne Realty Board for their financial assistance in the publication. Thanks are also due Mr. Lawrence V. Sheridan, Mr. A. W. Brayton, Jr., Fairchild Aerial Surveys, Inc., of New York and various City Plan Commissions for their help in supplying illustrations.

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A City Planning Primer

CHAPTER I

THE BUILDING OF CITIES

The history of ancient nations is principally the history of the cities of those nations. A history of Greece without the story of Athens is impossible. Italian history is, at least until very recently, a story of Rome, of Venice and of Genoa with their political, artistic and scientific achievements.

A country may decline, decay and even vanish, politically, but the legendary beauty and glory of its cities will survive. The hanging gardens of Babylon and the temples of ancient Egyptian cities excite our imagination and wonder, even though buried beneath the dust of centuries.

The oldest civilization of which we know today is that of ancient Egypt. Probably as early as 5000 B. C., the Egyptians had developed in the valley of the Nile an advanced civilization.

Among the larger cities which were built by the Egyptians were Memphis, Thebes and Alexandria. Of these Memphis was the most ancient, while Thebes was probably the most beautiful.

Thebes has been partly uncovered and attempts have been made to verify the legends of its magnificence. It was located on the banks of the Nile and had a very excellently developed series of quays.

Within the city were temples erected under the direction of the king and by the labor of thousands of slaves. The temple walls and columns were brilliantly painted; in fact some historians tell us that gold leaf and pure gold ornaments were not uncommon.

The streets of the city were, in comparison with our present day standards, rather narrow and the whole system of streets very irregular.

Other important ancient cities which are described by historians are Babylon, Athens and Rome. The traditions of Babylon center around her hanging gardens; of Athens and Rome about the beauty of their public buildings.

The art of city building during the middle ages did not show any marked advance. In fact no city founded during that time compared favorably with those of the ancient civilizations. Cities of that age were all surrounded by high walls. The street plans were usually very irregular, the streets themselves narrow. The irregular alignment of the streets made possible a much easier defence against an invader who was strong enough to penetrate the outer walls.

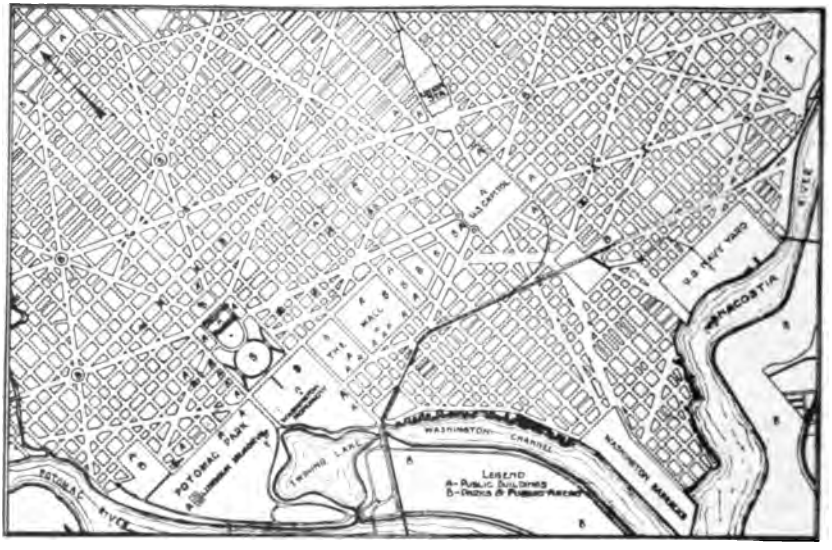
Of the great cities of the world of today, there is evidence that in early times some parts of them were planned with a view to

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Courtesy of Fairchild Aerial Surveys, Inc.

An Aeroplane View of Washington, D. C.



The ground plan of Washington is considered one of the best in the world.

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their convenience and beauty, but it is in general true that our cities have grown up without any previous planning and to a great extent are still without large plans of orderly development. Two conspicuous instances of deliberate planning of a great city in advance suggest themselves: Washington, which has in part at least been developed in accordance with the original design, and Canberra, the new capital of Australia, as yet in its earlier formative state. Only in rare instances have great cities begun large undertakings of replanning which involve at one time radical changes in the street plan or the abandonment of existing public buildings in order that broad avenues, civic centers and imposing public buildings might appear. The enormous cost, the inertia of public sentiment and the opposition of property owners have prevented. London missed its great opportunity when, after the great fire, vested interests prevented the rebuilding according to Wren's plans. Likewise, America has seen similar opportunities lost in Boston, Chicago, San Francisco and Baltimore. Paris and Vienna present the two notable examples of replanning on an elaborate scale.

CHAPTER II

THE GOVERNMENT AND PLANNING OF CITIES

Throughout our country there are county and township governments, or both, which serve the political needs of the rural localities for which they were originally designed. But whenever a considerable number of people establish their homes and their businesses in close proximity, there arise additional community needs and interests which are not shared by their more widely scattered neighbors on the farms. These community needs may, at first, be satisfied by voluntary cooperation through neighborhood clubs or associations. But as the group becomes larger and its needs become more numerous and complex, some persons will be unwilling to cooperate. Whenever the failure of some to cooperate imperils the welfare of the whole community there must be power to compel the unwilling ones. Thereupon a town is organized and the state confers upon it a government with power to plan common improvements and to carry them out. When the town becomes larger and its problems more complicated a city with a more elaborate form of government replaces the town organization.

The desire of many people to become residents of cities is apparent from a study of our population statistics. For instance, we learn that in 1890 twenty-seven per cent of the population of Indiana lived in incorporated cities; in 1900, thirty-four per cent; in 1910, forty-two per cent, and in 1920, fifty-six per cent.

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Whether or not this change of population from rural to urban is a beneficial one is not a question to be discussed here. The fact is that this change has been made and in comparatively few years.

The government provided for a town is very simple. It consists of a board of trustees, and a treasurer, clerk and marshal. These officials make provision for and carry on a considerable number of services of a purely local character, such as fire protection, streets and sidewalks, street lighting, schools and cemeteries. They are empowered to make and enforce police regulations and to levy and collect taxes.

Any town in Indiana having a population of two thousand may become a city, thereby taking on a more elaborate form of government having more powers.

Indiana cities are divided into five classes based primarily upon population. Three forms of government are provided for by law, and cities may choose the one under which they prefer to be governed. These are the mayor-council, the commission and the manager forms. The mayor-council form, which is the oldest and which might be termed the normal form in Indiana, is substantially the same for cities of the first four classes. The city council is the legislative body, making ordinances and levying taxes and appropriating money. The administrative work is grouped, for the most part, in six departments: finance, law, public works, public safety, assessment and collection, and public health and charities. The heads of these departments are appointed by and are under the direction of the mayor. There is a department of parks under a park board.

The plan just sketched is modified considerably for cities of the fifth class. This class includes cities between ten thousand and twenty thousand population having an assessed valuation of less than five million dollars and all cities of less than ten thousand population. Here the administrative machinery is more simple and the work is carried on, chiefly, under the direction of the city council.

The General Assembly of Indiana in 1921 enacted a law whereby any city so voting may adopt either the commission or the manager form of government. Down to the present time but one city, Michigan City, has acted under the law, although some three hundred cities in the United States have adopted one of these forms during the last ten years. Under either of these systems a commission elected by the voters takes over all the powers of the mayor, council and executive departments. In the commission form the commissioners individually act as heads of the several departments. Under the manager form the commission appoints a city manager who is head of the whole administrative work acting under the supervision of the commission.

Whatever the form of city government, the work to be done by the city is the same. Those elected to office must see that the citizens have adequate fire and police protection; that the water supply is sufficient and of proper quality; that wastes are disposed of with

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the least menace to health and comfort; that streets are provided for the transport of citizens and commodities from one part of the city to another, and that these streets are kept clean and in repair; that public utility companies or the municipality provide at reasonable cost such things as street car service, telephones, light and power; and that parks and playgrounds are conveniently located and adequate, and that educational opportunities are offered to the children of the citizens.

All of these activities involve the expenditure of large sums of money which must be provided by the citizens through the payment of taxes and special assessments. If city and town governments are to justify themselves, their administration must be in the hands of honest and capable persons who will carry on the work of the city efficiently and economically.

An unfortunate consequence of the habit of injecting party politics into city government is that the city officials change at such frequent intervals that it is impracticable to plan city work far in advance. There is no assurance that succeeding administrations will adhere to plans already made. Much money is thus wasted and much careful planning rendered futile. When most of our older cities were laid out, the founders had no vision of what the future development would be and, consequently, failed to plan on a scale to fit the needs of today. In other cities, where original layouts were sufficiently generous, later generations unwisely allowed encroachments to be made on the original plan or failed to see to it that later additions were made to conform to earlier plans.

Fortunately the ultimate cost of such haphazard growth is becoming more and more apparent, and through the application of two laws, which passed the 1921 session of the state legislature, it is hoped that in Indiana this method of development of our cities will soon become obsolete.

These laws are known as "The City Planning Law" and "The Zoning Law." An appendix to this pamphlet gives a synopsis of the City Planning Law.

Under the provisions of these laws the following cities of Indiana have formed City Plan Commissions: Anderson, Batesville, Crawfordsville, Elkhart, Evansville, Gary, Indianapolis, Kokomo, Marion, Mishawaka, Muncie, Michigan City, Newcastle, Princeton, Richmond, South Bend, Terre Haute, and Valparaiso.

Thus through the application of these two enabling acts, a great many cities in Indiana are entering upon a new era in city building and the time is not far distant when most of the cities in the state will be exercising a definite control over their physical development.

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CHAPTER III

ZONING

In the development of a City Plan for any community, certain features of the problem are outstanding in importance. Satisfactory solutions of these feature problems determine the ease with which the details of the whole plan can be worked out.

These feature problems are zoning, street system, transportation and recreation facilities. All are so intimately related that an attempt to solve either without careful consideration of the other three gives unsatisfactory results.

The problem which affects the individual citizen most and which has an immediate and at the same time a far reaching effect upon the orderly development of the city is the zoning problem.

Mr. Herbert Hoover, Secretary of Commerce, is very much interested in the zoning of our cities and because of his interest appointed an Advisory Committee on Zoning to the Division of Building and Housing of his department. This Advisory Committee made up of housing and zoning experts have worked out and distributed a Zoning Primer, which may be secured by any citizen by writing to the Division of Building and Housing, Department of Commerce, Washington, D. C. The Primer sets forth the zoning idea and practice in such an admirable way that it was thought advisable to include in this pamphlet the following quotations:

What Is Zoning?

"Zoning is the application of common sense and fairness to the public regulations governing the use of private real estate. It is a painstaking, honest effort to provide each district or neighborhood, as nearly as practicable, with *just such protection* and *just such liberty* as are sensible in *that particular district*. It avoids the error of trying to apply exactly the same building regulations to every part of a city or town regardless of whether it is a suburban residence section, or a factory district, or a business and financial center. It fosters civic spirit by creating confidence in the justice and stability of the protection afforded.

"Zoning gives everyone who lives or does business in a community a chance for the reasonable enjoyment of his rights. At the same time it protects him from unreasonable injury by neighbors who would seek private gain at his expense.

"Zoning regulations differ in different districts according to the determined uses of the land for residence, business, or manufacturing, and according to the advisable heights and ground areas.

"But these differing regulations are *the same for all districts of the same type*. They treat all men alike."

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Why Do We Need Zoning?

"Some one has asked, 'Does your city keep its gas range in the parlor and its piano in the kitchen?' That is what many an American city permits its household to do for it.

"We know what to think of a household in which an undisciplined daughter makes fudge in the parlor, in which her sister leaves soiled clothes soaking in the bathtub, while father throws his muddy shoes on the stairs, and little Johnny makes beautiful mud pies on the front steps.

"Yet many American cities do the same sort of thing when they allow stores to crowd in at random among private dwellings, and factories and public garages to come elbowing in among neat retail stores or well-kept apartment houses. Cities do no better when they allow office buildings so tall and bulky and so closely crowded that the lower floors not only become too dark and unsatisfactory for human use, but for that very reason fail to earn a fair cash return to the individual investors.

" 'Live and let live' is a better motto for the modern city than the savage one of 'dog eat dog'.

"It is this stupid, wasteful jumble which zoning will prevent and gradually correct. We must remember, however, that while zoning is a very important part of city planning, it should go hand in hand with planning streets and providing for parks and playgrounds and other essential features of a well-equipped city. Alone it is no universal panacea for all municipal ills, but as part of a larger program it pays the city and the citizens a quicker return than any other form of civic improvement."

Zoning Protects Property and Health

"Suppose you have just bought some land in a neighborhood of homes and built a cozy little house. There are two vacant lots south of you. If your town is zoned, no one can put up a large apartment house on those lots, overshadowing your home, stealing your sunshine and spoiling the investment of 20 years' saving. Nor is anyone at liberty to erect a noisy, malodorous public garage to keep you awake nights or to drive you to sell out for half of what you put into your home.

"If a town is zoned, property values become more stable, mortgage companies are more ready to lend money, and more houses can be built.

"A zoning law, if enacted in time, prevents an apartment house from becoming a giant airless hive, housing human beings like crowded bees. It provides that buildings may not be so high and so close that men and women must work in rooms never freshened by sunshine or lighted from the open sky."

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WHY DO WE NEED ZONING?



An unwelcome neighbor Zoning establishes industrial districts and separates them from dwelling house districts.



Side yard restrictions are a necessary part of zoning ordinances. They prevent crowding such as this.



The apartment house robs many a small home of its just share of light and air.

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WHY DO WE NEED ZONING?

The closed porch is another usurper when built out even with open porches.





No set back lines and no restrictions as to use cause such conditions as these.

In a residence district, small store buildings projecting out to the sidewalk cause loss in value to all homes in the neighborhood.



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A Zoning Program

"Surveys.—A zoning ordinance needs to be based on a comprehensive and detailed study of the precise *local conditions,* both present and prospective. What fits one city or town may be a bad misfit for another. There is no short cut to good zoning in any community through blindly accepting what has been done for another community. The only safe path is a thorough, open-minded examination of the facts in each community as to existing uses, existing densities, and heights of buildings, the customs of the people, and the trend of affairs. In every city there are citizens and organizations having in their possession valuable knowledge of local conditions. These have a large contribution to make to those responsible for zoning, although those who have lived their whole lives in a community do not necessarily realize all that is going on about them.

"The zoning of a city requires expert professional knowledge just as the presentation of a case in court requires legal training. But just as the lawyer depends upon the layman to secure his facts, so must the professional zoning expert call upon the citizens for much of the accurate information upon which any good zoning regulations must be based.

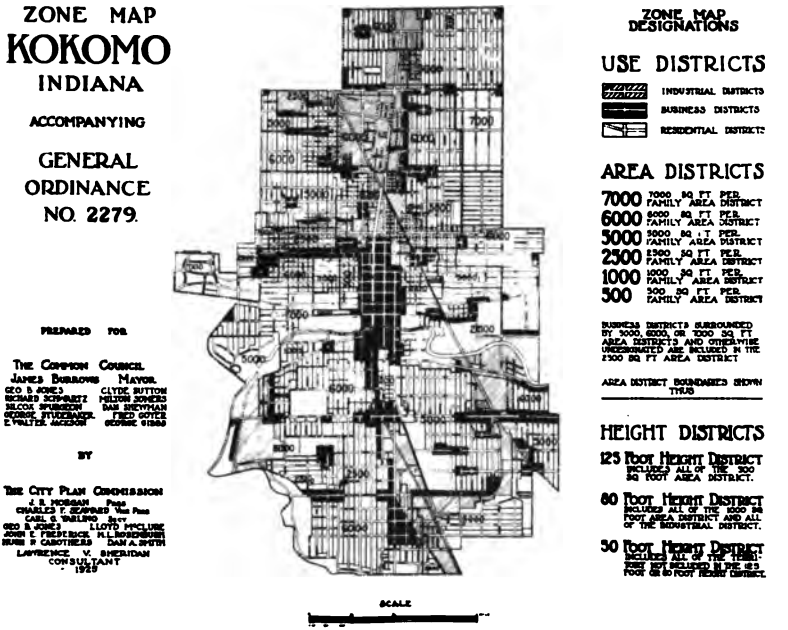
"Technical Advice.—The practice of zoning is relatively new in America. We are feeling our way and must learn by experience. Those who have had experience tend to become expert, with broader knowledge of practices that are proving effective. These men are becoming gradually more skilled in the methods of getting at the essential facts of any local situation, and in the interpretation of those facts. If they possess insight and sane judgment, their advice becomes increasingly valuable.

"Scope of a Zoning Ordinance.—A zoning ordinance consists of one or more maps dividing the city into different kinds of districts; and a statement of methods of regulation to be employed in each district in regard to the use to which property may be put, the height and size of buildings, and the amount of space to be left vacant, with adequate provisions for enforcement.

"Getting Public Support.—In the process of drafting a tentative ordinance, it is important, by means of full public discussion, to be sure that the ordinance is an 'application of common sense and fairness' and will 'provide each district, as nearly as practicable, with *just such protection* and *just such liberty* as are sensible in that particular district.' It is essential likewise to be sure that public opinion, as a whole, will support it.

"Zoning in Operation.—A zoning ordinance is of value only as it is properly enforced. Because of the difficulty in making with precision the forecasts on which it is based, its operation should be closely followed by those who most intimately understand the reasons for its provisions. Thus, improvements and adjustments may

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ZONE MAP
KOKOMO
INDIANA
ACCOMPANYING
GENERAL
ORDINANCE
NO. 2279.
PREPARED FOR
THE COMMON COUNCIL
JAMES BURROWS MAYOR.
BY
THE CITY PLAN COMMISSION
LAWRENCE V. SHERIDAN
CONSULTANT
1929
ZONE MAP DESIGNATIONS
USE DISTRICTS
INDUSTRIAL DISTRICTS
BUSINESS DISTRICTS
RESIDENTIAL DISTRICTS
AREA DISTRICTS
7000 7000 SQ FT PER FAMILY AREA DISTRICT
6000 6000 SQ FT PER FAMILY AREA DISTRICT
5000 5000 SQ FT PER FAMILY AREA DISTRICT
2500 2500 SQ FT PER FAMILY AREA DISTRICT
1000 1000 SQ FT PER FAMILY AREA DISTRICT
500 500 SQ FT PER FAMILY AREA DISTRICT
BUSINESS DISTRICTS SURROUNDED BY 5000, 6000 OR 7000 SQ FT AREA DISTRICTS AND OTHERWISE UNDESIGNATED ARE INCLUDED IN THE 2500 SQ FT AREA DISTRICT
AREA DISTRICT BOUNDARIES SHOWN THUS
HEIGHT DISTRICTS
125 FOOT HEIGHT DISTRICT INCLUDES ALL OF THE 500 SQ FOOT AREA DISTRICT.
80 FOOT HEIGHT DISTRICT INCLUDES ALL OF THE 1000 SQ FOOT AREA DISTRICT AND ALL OF THE INDUSTRIAL DISTRICT.
50 FOOT HEIGHT DISTRICT INCLUDES ALL OF THE AREA NOT INCLUDED IN THE 125 FOOT OR 80 FOOT HEIGHT DISTRICT.
SCALE

Nine cities of Indiana have worked out zoning plans. Others will soon realize the value of such plans.

from time to time be made intelligently. It is to furnish in exceptional cases a means for remedying possible injustice that, in some States, provision is made for a board of adjustment or appeals.

"It is obvious from the nature of the case that, even if a zoning ordinance were drawn with superhuman perfection, time and the natural growth of the community might show the need of modifications. The purpose of a zoning ordinance is not to stifle growth, but only to insure that instead of taking place sporadically and wastefully it shall go on in an orderly way, in response to generally recognized needs and with due notice to all concerned."

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CHAPTER IV

STREETS AND STREET SYSTEMS

The greatest handicap which can be placed upon a growing city is an inadequate and poorly arranged system of streets. No one feature of the civic structure plays as important a part in orderly physical development. The assurance of well paved and properly located streets with sufficient width between curbs to take care of the traffic attracts not only business men and manufacturers to a community, but is also an argument of considerable weight to the prospective home builders.

To accommodate properly the street traffic, certain streets of the system must be located and designed to handle the through traffic, that is, traffic moving from one part of the city to another or from the city to another city a few miles away. These streets are called major or arterial thoroughfares. They are characterized by wide pavement, long, almost straight alignment and comparatively flat grades. These major streets form the skeleton upon which all other streets in the system are hung.

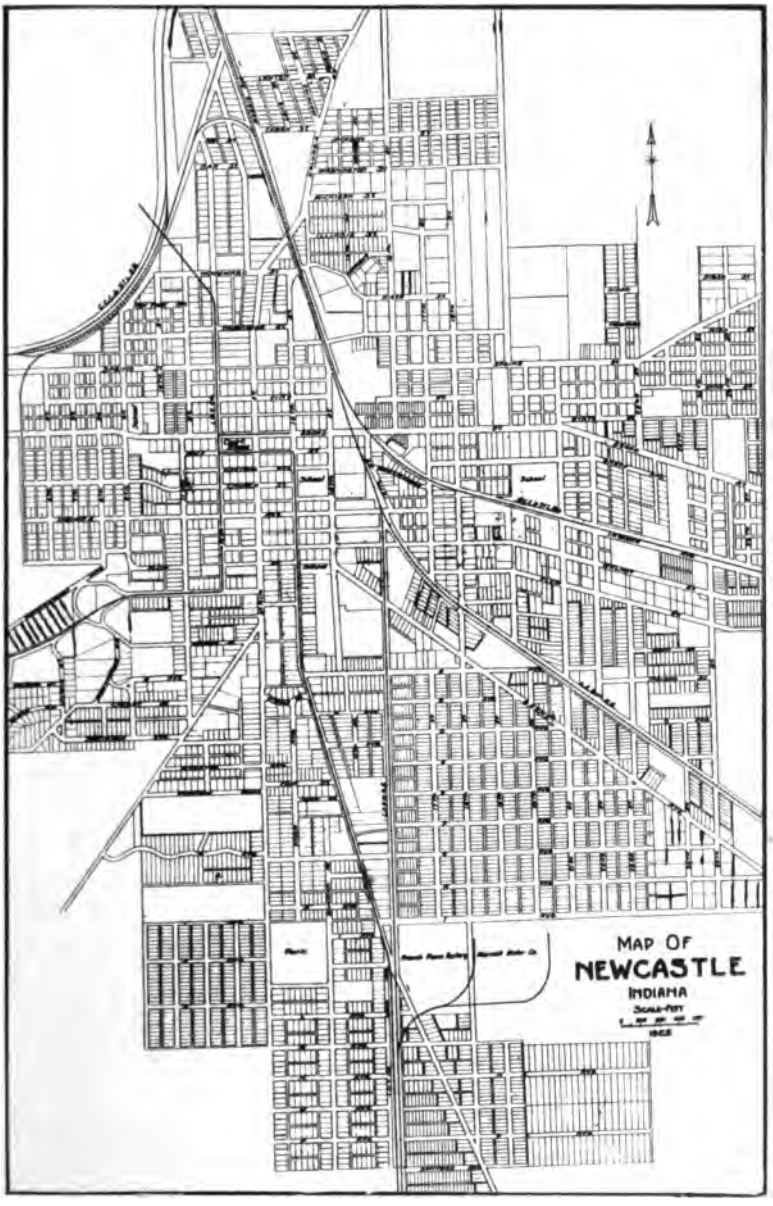
Secondary streets act as feeders to the main thoroughfares, while the minor or local streets serve as lanes of access to the homes of the citizens.

It is obvious that the width and kind of pavement, width of sidewalk, and width of lawn space, on any street depend upon two things; first, the zone or district which the street serves, and secondly, the particular classification of the street. In short, the principle of adaptation to the use to be made of it instead of adherence to some uniform rule should control in the design of our streets.

Our state law gives to the city plan commission the power to accept or reject the plats of new subdivisions not only within the city limits, but also within a five mile limit outside the city. This provision should prove of great value to the future city because through the application of that power, the commission can gradually develop a coordinated system of streets, which will conform to the topography of the site of the city. As a result of refusing to approve plats of land upon which the street layout does not conform to the general plan made for that part of the city, jogs, dead-ends and bottle necks will be as rare in the future as they are common in the present city street systems.

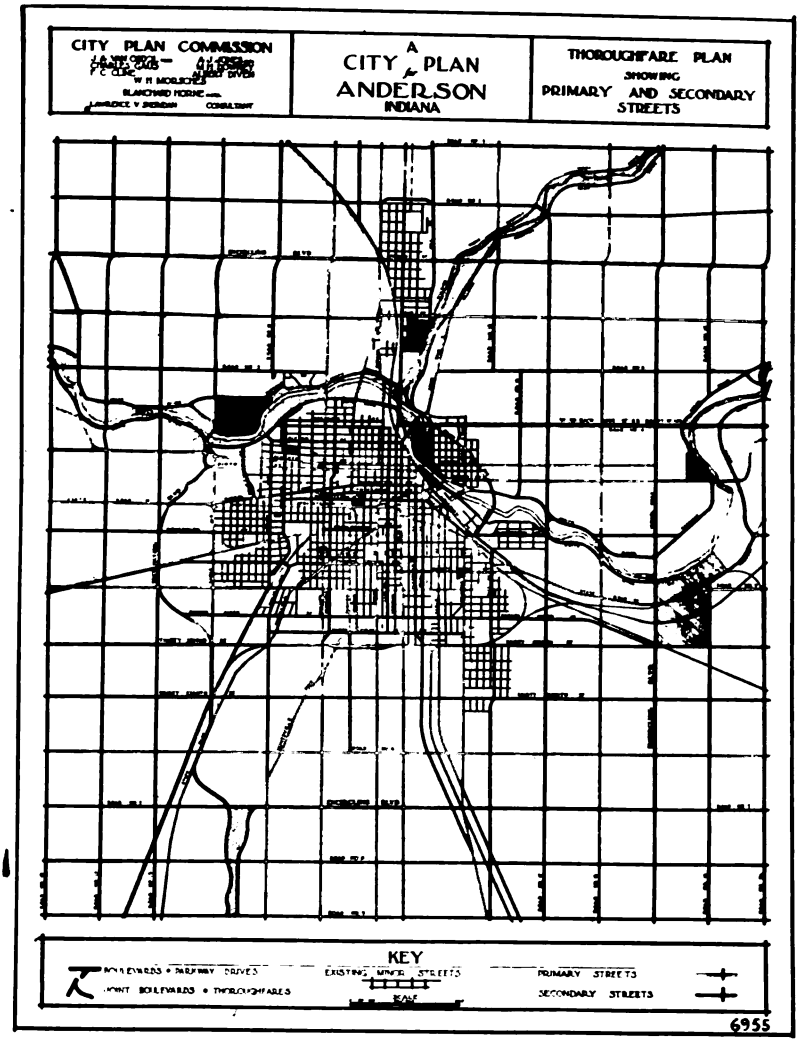
Until the time when the automobile became a common means of transportation, traffic on city streets needed little regulation. The flow of traffic even in our larger cities was slow and fairly uniform. As the number and types of automobiles increased, the mixed character of the traffic, motor driven and horse drawn, pleasure vehicles and trucks, resulted in a complex traffic problem which is today far from being solved.

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The plan of Newcastle very clearly illustrates the lack of planning. Notice the large number of dead end streets and jogs, the separation of the whole area into several sections by the railroads and the apparent lack of supervision of the platting.

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The development of a thoroughfare plan is a very important step in city planning.

The police departments of our larger cities have found it necessary to appoint special officers to oversee and regulate the street traffic. Special traffic signs and signals have been developed in an effort to eliminate the dangers and delays due to the congested conditions existing in our down town districts, while special parking and driving regulations are found necessary to relieve the new conditions.

The solution of the traffic congestion problem, if there is a solution, is a part of the replanning problem of our cities. What the final result will be can hardly be foreseen. Some authorities assert

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Broad Street, Newcastle—Even in our smaller cities the traffic problem is a real one. Notice, also, the large number of advertising signs.

that decentralization of business is the proper and only feasible solution. Others maintain that streets must be widened either by cutting through the buildings or arcading the sidewalks. The facts are that when the streets were originally laid out, there was no anticipation of the automobile or the high office building, both of which are direct contributors to the traffic problem.

An ideal system of streets in any city is one that provides efficiently for the flow of traffic. In an ideal arrangement, the streets in the retail district would be laid out in a rectangular pattern. Leading from business or manufacturing centers, there would be broad diagonal thoroughfares and in the outlying areas the homes of the citizens would be located on streets, the arrangement of which would depend upon the topography of the site.

In the ideal layout, streets would vary in width. Enough paved area would be devoted to traffic purposes and no more. The zoning plans would enable the designer to anticipate his traffic needs and design each street to satisfy those needs.

Our real problem in street planning today is to take what exists in our cities and try to approach the ideal arrangement. Few cities are wealthy enough to afford the expense incident to cutting new diagonal thoroughfares through built up blocks, nor is it always advisable to do so.

A study of the situation and a vision of the future accompanied by the application of a large amount of common sense are all neces-

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The curved street is used to best advantage in residence districts.

sary to a reasonable solution of the problem. Certain streets will be found to be too narrow, others too wide. The objection to the streets which are too wide is the excessive cost of paving and maintenance. This can be well taken care of by devoting a greater width to the grass plot which could later be made more narrow if traffic needs should make it necessary. As for the streets which have been found too narrow, the time to widen is before the street is bordered by tall business buildings or apartment houses.



Greenfield, Indiana—An attractive and well designed residence street. The street trees are an important part of the design.

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CHAPTER V

TRANSPORTATION

From the sleepy-eyed camel jogging along an ancient Theban street to the Los Angeles floating over Washington is a long step in the advancement of civilization. The lapse of time between the camel and the airship is about sixty centuries. Practically all of the change in our methods of transportation has been made during the last hundred years.

Although steam and electricity have made possible the city building of today, they have, at the same time, brought transportation problems of much difficulty. The problem is closely connected with the street plan and can be worked out only with that in mind. Railway rights of way, grade crossings, and terminals in combination with narrow streets and heavy traffic present awkward puzzles. The solution must take into account railway tracks and terminals, interurban and street railways and, lately, motor bus lines as well. The transportation problem is not a series of individual problems dealing with a single form of transportation, but all forms must be coordinated into an evergrowing, single transportation system.

Railways should be induced to elevate or depress tracks and to consolidate passenger terminals at some convenient location. Such union terminal must be accessible by streets adequate to the volume and character of the traffic which will result. Freight terminals accessible by wide streets with heavy-service paving, and having



A Dangerous Grade Crossing, Indianapolis—Elimination of these is a part of a complete city plan.

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East Washington and Noble Streets, Indianapolis—Grade separation results in better traffic conditions and materially decreases traffic accidents.

adequate track facilities both at terminals and in the industrial district are of the highest importance to any considerable commercial or industrial development.

The adjustment of the problem presented by the desire of every individual to be set down at the business center on the one hand, and the necessity of avoiding an intolerable congestion at that point seems to offer no single best solution. It has been met usually by looping car lines without coming to a common point or by through routing of cars. Care must be taken to secure adequate and convenient car or bus service between the residential and the industrial sections. Bus service may be made to provide crosstown needs which have seldom been adequately cared for by street railways. The solution of the housing problem, always a troublesome one, depends to a large degree on transportation to the industrial district.

Efficiency in the collection and distribution of passengers and goods is the goal to which transportation efforts are to be directed.

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CHAPTER VI

PARKS AND RECREATION FACILITIES

The desire on the part of citizens of a community for parks and playgrounds is a natural one and the need for open spaces in the city, set aside for recreational purposes and for adornment of the civic structure, has been recognized in all ages. Many ancient cities were noted for their public parks and the beauties of the grounds surrounding their public buildings. In modern times practically all cities have parks and there is little opposition to the use of public money for park purposes. In fact, park commissions existed in cities years before serious thought was given to city planning as a function of the city government.

It is hardly necessary to point out that the design of a system of parked areas with connecting drives or boulevards must be developed simultaneously with the street system, and that the zoning plans make possible the anticipation of park needs in the different sections of the city. This results in a saving in that these areas can be secured at a lower cost before the adjacent lots are built up.

Cities differ in character and vary in need for parks. The number of parks or the number of acres devoted to parks which each city should have is a matter which cannot be definitely stated. Each city has its own problem; each park area its own peculiarity and its proper development is an individual problem.



A scene in Henry County [illegible]

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The Wabash River bank at Lafayette—The usual treatment of a river front.

Certainly, whenever a water feature exists within the city, such as a stream or lake, the banks should be set aside as park space. This adds not only to the attractiveness of the city, but also removes the usual unsightly and unhealthy conditions and prevents encroachments on the river bed which so often prove disastrous in times of flood.



Fall Creek, Indianapolis—An ideal treatment of a stream bank.

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Park areas vary greatly in size from the small triangle at a street intersection to the thousand acre municipal forest or country park. The location, use and size determine the character of the development. For the small triangle, grass and a few trees are all that are required while the larger parks need in some cases elaborate planting and grading plans.

As a general rule and for the average Indiana condition, the city park need not be elaborately developed. Most cities have but one or two parks and these are used intensively. Provision for the greatest number of users should be the object of the park superintendent. Playground space may be set aside for the children and if size permits, tennis courts and baseball diamonds may find their places in the design.

Trees and shrubs are the materials used by the landscape designer to create pictures, and it is in the location and planting of these that the park authorities need advice. There is so much to gain by a good design and so much of real value to lose by planting according ot a poor design, that too much emphasis on the necessity for the services of an expert cannot be made.



Rochester Court House, 1925—This is one of the finest buildings of its kind in the state. It needs landscape treatment in order to bring out its full value.

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The Court House at Delphi, 1925—In a few years the shrubs and trees will add materially to the beauty of this fine structure.

The planting and care of the grounds surrounding our public buildings should be left to the park commission. It is here that altogether too many cities in the state are lacking. As a general rule, the architectural values of our court houses and city halls are creditable. The settings, however, are not what they should be.

Public school buildings and grounds are subject to practically the same criticism as the other public buildings. To give it space worthy of our modern conception of the needs of the high school student of today, the high school building should be located on an area large enough to accommodate all necessary accessory buildings and in addition provide sufficient playground space.

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The working out of a city plan for Madison would, without question, soon eliminate this ditch which runs through the city.



Slum conditions are sometimes found in our small Indiana cities. A zoning ordinance makes possible the gradual elimination of such unhealthy surroundings.



Back yard scenes such as these are possible in all cities and towns. City planning and zoning principles applied to city building produce such pictures.

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APPENDIX A

SYNOPSIS OF THE INDIANA CITY PLANNING LAW
(Laws of 1921, Chapter 209; Laws of 1923, Chapter 92)

The city council of any city may create by ordinance a city planning commission.

The commission takes one of two forms:

(a) It shall, except in cases mentioned under "(b)" below, consist of nine members, five being citizens holding no other office and appointed by the mayor, together with one member of the city council appointed by that body; one member of the park board, the president of the board of public works, and the city engineer;

(b) If the city does not have a board of park commissioners, a board of public works or a city engineer, then the commission shall consist of seven members. At least four of these shall be citizens not holding other public office. The council shall designate what officials shall make up the remaining number, with the restriction that not more than one shall be a member of the council or of any one board.

The five appointive members of the commission have overlapping terms of office, one member of the first five serving for two years, two others for three years, and the remaining two for four years; after the original terms expire, all terms thereafter being made four years. All members serve without compensation except for actual expenses incurred. The commission may appoint a secretary, and such engineers, architects, and employees as are deemed necessary.

The Commission shall have power:

(1) To make surveys, studies, maps, and plans of a whole or parts of the city and of the surrounding country;

(2) To make recommendations as to the location, width and arrangement of streets and other public ways, bridges, and docks; the location of parks, playgrounds, public buildings, and improvements; the removal, relocation, or extension of existing public works; the platting of ground into lots, streets, and alleys, and the location, relocation, and development of means of communication.

(3) To prepare and submit to the council for its adoption ordinances regulating the height, area, and use of land by districts within the city, and regulating the location of particular kinds of business and the erection of structures for particular uses, in the inest of the safety, health, morals, comfort, and convenience of the public.

(4) To make studies as to housing conditions.

(5) To carry out instructions of the council for enforcing the city plan.

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(6) To make recommendation upon any proposed statuary, memorial, public structure, or appurtenance before a permit may be issued for the erection of the same.

(7) To pass upon all plats or re-plats of lands laid out in lots or parcels, with the portions designed to be dedicated to the public use within the city or within five miles thereof, before such plats shall be received for record.

The city council shall appropriate and there shall be included in the tax levy an annual tax of not less than three mills nor more than five cents on each hundred dollars of taxable property. The proceeds of such levy shall be under the exclusive control and at the disposal of the commission.

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PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE

Circulars

*CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

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BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright, 1922.

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CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

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* Out of print.

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BULLETIN OF
PURDUE UNIVERSITY
PUBLICATIONS OF THE ENGINEERING DEPARTMENTS

Use and Care of Farm-House Telephones

BY
R. V. ACHATZ

BULLETIN No. 12
ENGINEERING EXTENSION
LAFAYETTE, INDIANA

Published by Purdue University at LaFayette, Indiana

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THE ENGINEERING EXTENSION DEPARTMENT OF PURDUE UNIVERSITY

Purdue University recognizes its opportunity for public service by carrying the benefits of its teaching and research activities to those in the State who are interested in engineering problems, but who are unable to be benefited by the regular courses of resident instruction which are offered at the University.

The Engineering Extension Service of Purdue University is carried on in the following ways:

1. Conferences are held at Purdue University and at other places in Indiana for the benefit of road builders, farmers, electrical workers, power plant men, foundrymen and for others engaged in manufacturing and in public utility industries.

2. Groups of lectures are delivered by engineering experts of Purdue University for the benefit of industrial workers and executives. Talks are also given on subjects related to engineering before civic, commercial and manufacturing organizations.

3. Publications, in the form of bulletins and circulars are issued containing up-to-date information on engineering subjects.

Address communications concerning Engineering Extension Service to

ENGINEERING EXTENSION DEPARTMENT,
Purdue University, LaFayette, Indiana

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BULLETIN NO. 12
ENGINEERING EXTENSION DEPARTMENT

Use and Care of Farm-House Telephones

BY
R. V. ACHATZ
Engineering Extension Specialist in
Electrical Communications

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
DECEMBER, 1925

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Use and Care of Farm-House Telephones

INTRODUCTION

In Indiana there are several hundred mutual and co-operative telephone associations with several thousand connected telephones. In very many cases the lines have been built by the association and the instruments have been bought and installed by the individual members. In many of these organizations, no regular troubleman is employed and each member is supposed to maintain his own telephone instrument and section of the line. Frequently the service over an instrument or even on an entire line is interrupted by some defect which could easily be remedied were the proper information at hand. This circular is intended to provide information to assist in the proper care and use of the telephone. It is prepared, primarily, for those who have had little or no telephone experience, therefore, technical terms and descriptions have been eliminated as far as it is possible.

WHAT THE TELEPHONE IS

The telephone is an instrument for transmitting speech by electrical means. It consists of two groups of parts; one group used for transmitting and receiving the voice and the other group used for sending and receiving signals so that the users may call and receive calls. While the parts are necessarily delicate, they are not so complicated but that many ordinary repairs can be made by the owner of the instrument. The operation of a telephone is no more mysterious than that of an automobile, a sewing machine or a cream separator; devices that are in use everywhere and which are generally taken care of and operated by the user. Unlike these devices, however, the telephone only infrequently requires attention. It is so designed that it does not require frequent cleaning, oiling and overhauling. Ordinarily, the only time a telephone needs attention is when the batteries become exhausted or when some kind of trouble occurs. Until the telephone fails to operate properly, it is best left alone. When repairs are needed they should be promptly made and in a permanent manner.

FUNCTIONS OF THE VARIOUS PARTS

If the home user of the telephone is to be able to give the instrument its ordinary care some understanding of the use of the various parts is helpful. Therefore, there is given the following

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scription of the parts most commonly found in the rural line telephone. Fig. 1 shows an outside and an inside view of a typical instrument with the various parts indicated.

Transmitter.—The transmitter is the device for receiving the sound waves produced by the voice and for converting them into the proper type of electrical impulses.

Battery.—The battery usually consists of two or three dry cells to provide the current for the transmitter. A common mistake is the belief that the battery has other duties. It has nothing to do with sending or receiving rings or with receiving speech. A telephone will do all of these things just as well if the battery is removed entirely.

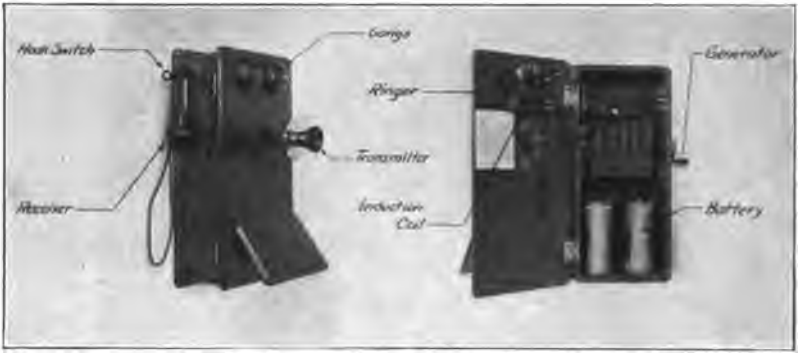


Fig. 1. Parts of the Telephone.

Induction Coil.—The induction coil is a spool which has two windings of wire. The inside winding is of rather large wire and is called the primary. The outside winding consists of many turns of fine wire and is called the secondary. The primary winding is connected to the transmitter and battery and the secondary winding is connected to the receiver and the line. The purpose of the induction coil is to "step-up" or to increase the voltage or electrical pressure of the electrical impulses produced by the transmitter, so that they may be transmitted over the wire of the line. In a way, the action is similar to that of a spark coil used in gas engine ignition.

Receiver.—The receiver is the device for converting into sound waves the electrical impulses received from the line. This is done by causing vibration of a thin iron plate called the diaphragm.

Hook Switch.—The hook switch is the device upon which the receiver hangs when the telephone is not in use. It serves, not only as a convenient place for the receiver, but it also is arranged

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to make a connection of the receiver to the line. It also makes a connection of the battery to the transmitter when the lever moves up as the receiver is lifted.

Ringer.—The ringer is the device for receiving calls. It consists of two spools or coils of wire, a permanent magnet, a vibrating part mounted on pivots and a clapper rod for striking the gongs. Ringers are ordinarily designated as 1000 ohms, 1600 ohms or 2500 ohms depending upon the resistance of the wire on the coils. 1600 ohms is perhaps the most commonly used on farm line telephones but for most lines any of the three types will operate satisfactorily. As a general rule the longer the line and the larger the number of telephones, the higher should be the resistance of the ringers. *The important thing, however, is that the resistance of all the ringers on the same line should be the same.* In the past, ringers as low as 80 ohms have been made for use on private lines but they will not operate satisfactorily on party lines. If such a telephone is connected to a party line it will prevent the proper operation of the other telephones on the line. On a farm line connected to a certain Indiana telephone exchange, one of the members had such a telephone and he was very proud of the fact that his telephone was "stronger" than any of the others on the line. As a matter of fact, his ringer prevented the other telephones from getting their proper share of ringing and talking current and the other members received very poor service because of this telephone.

Generator.—The generator furnishes the electric current for ringing the bells on the line. It is really a small, hand driven dynamo. Generators are usually designated as three-bar, four-bar or five-bar depending upon the number of magnets. The power that a generator will deliver depends upon the number of bars or magnets, therefore, the number of bars should depend somewhat on the line. A three-bar generator is satisfactory for short and lightly loaded lines. A four-bar generator will serve for the ordinary line while the five-bar generator is needed for very long and heavily loaded lines.

Condenser.—The condenser is not always used in the telephone. When it is used, it is connected in the circuit of the receiver and is used to improve the ringing over a line when receivers are off the hooks. If five or six persons are listening on a line, it is often impossible to ring the switchboard or other parties on the line. If all instruments are equipped with condensers, the rings will be received nearly as well as if all the receivers were hung up. The size commonly designated as ½ mf. (micro-farad) is the one most frequently used.

Special Equipment.—In some cases telephones are provided with special devices such as push buttons for calling the switch-

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board without ringing bells on the line, etc., but their use is not common and they will not be considered here.

Connections of the Parts.—For the convenience of those who are interested, a simple diagram of the wiring connections of the various parts of the instrument is given in Fig. 2. Most of the later type telephones have a complete diagram of the wiring furnished with the instrument. By following the lines of Fig. 2, which represent wires in the instrument, it will be found that the transmitter, battery and the primary of the induction coil are in a circuit which is complete in the telephone itself. (The fact that a portion of the wiring between the induction coil and hook switch is used by another circuit also, does not change this condition.) The circuit from the line passes through the secondary of the induction coil and the receiver. Both of these circuits are connected when the hook is up

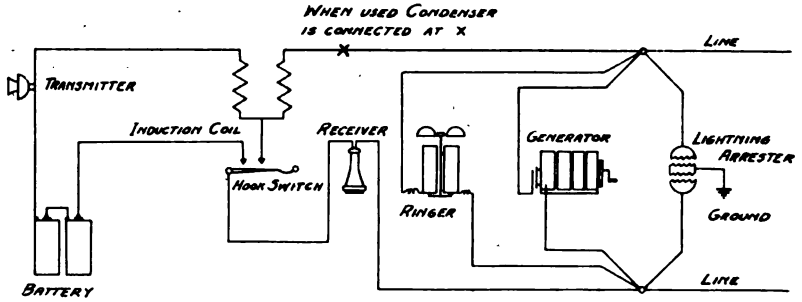


Fig. 2. Simplified Diagram of Connections of Bridging Telephone Instruments.

and disconnected when the hook is down. If a condenser is used it is connected in the circuit with the secondary of the induction coil and the receiver. The ringer is connected directly to the line or is "bridged" across the two line wires. The generator is also connected across the line wires when the crank is turned and a connection made by the springs mounted on the left hand side.

THE TELEPHONE INSTALLATION

Most rural telephones are installed on outside walls and it is usually convenient to bring the line wires to a point near the telephone so that elaborate wiring is not necessary. On account of this, only a few suggestions regarding the simpler forms of installation will be given.

Grounded and Metallic Lines.—Telephones may be connected either to metallic (two-wire) or grounded (single-wire) lines. In the latter case, the earth serves as a return circuit for the electric current. Grounded lines are probably most frequently used by cooperative telephone associations. They are the easiest to build and

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maintain but are subject to a number of difficulties which can not be avoided. These include noise during stormy weather, cross talk between lines where two or more lines run parallel for any distance, and induction noises from electric light lines. Metallic lines, well built and maintained, will eliminate most of these difficulties and will provide a better grade of service. However, a poorly built metallic line is likely to be in continuous trouble due to the swinging of the wires together or "short-circuiting."

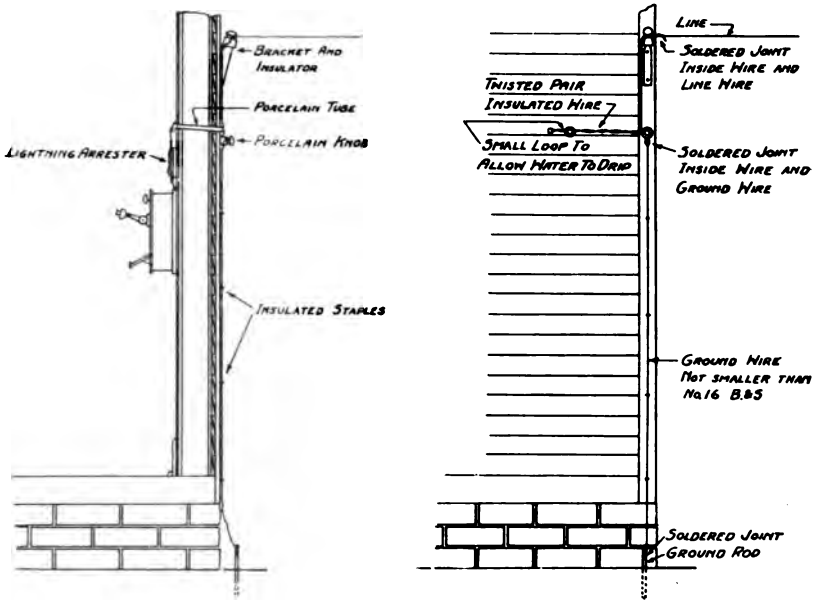

Bracket And Insulator
Porcelain Tube
Porcelain Knob
Lightning Arrester
Insulated Staples
Line
Soldered Joint Inside Wire and Line Wire
Twisted Pair Insulated Wire
Small Loop To Allow Water To Drip
Soldered Joint Inside Wire and Ground Wire
Ground Wire Not Smaller than No. 16 B.&S.
Soldered Joint Ground Rod

Fig. 3. Recommended Method for Wiring Telephone Installation on Ground Return Wire.

Details of the Installation.—In Fig. 3 is shown the method of installation that is recommended for grounded lines. For the wiring from the line wire to the instrument only copper wire with rubber and weatherproof cotton braid insulation should be used. The size of the wire should be No. 18 or No. 19 gauge (Brown and Sharp) and if twisted pair is used the job will be much neater. For fastening the wire between the protector and the telephone, a special staple with an insulating saddle or a special tack with an insulated head should be used. As these cost only a few cents a hundred, the use of plain tacks or staples has no excuse. Plain tacks and staples will rust and sooner or later cause trouble with the wire. Where the wire passes through the house wall, a small porcelain tube is recommended. This is the same type of tube used for electric light wiring. The hole for the tube should be bored so that the tube slopes down toward the outside to prevent water entering through

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the hole. A small loop of wire should be left at the outside end of the tube so that any water that collects on the wire will drip off rather than follow the wire through the tube. For metallic lines both wires should go to the line wires and a separate wire should be run from the ground wire to the ground binding post on the lightning arrester.

Ground Connection.—One of the most important parts of the installation is the ground connection. On it depends the proper operation of the lightning arrester and on grounded lines, the efficiency of the talking and ringing of the line depends much upon it as well. Cases of poor service can frequently be traced to poor ground connections. Short pieces of wire, wagon rods, etc., seldom make satisfactory ground connections. The rod should be long enough to reach down to damp earth, and large enough so that it is not likely to be broken or pulled out by accident. One company, after much trouble with ground connections, adopted the practice of driving a nine-foot length of ½-inch galvanized pump rod and making a soldered joint as shown in the drawing in Fig. 3. Ground connection troubles disappeared entirely.

Soldered Connections.—Another very important point is that all connections should be firmly soldered. Both copper and iron wire corrode when exposed to the weather. But if the two metals are in contact, the corroding action takes place much more quickly and a poor connection in the telephone wire results. To make a good soldered joint, the work must be made hot enough that the solder will flow freely into the space around both wires. Merely sticking a large mass of solder on the outside with a cold soldering tool will not make a good joint. Raw acid flux should never be used on copper wire; the acid remains in the joint and continues to eat away the copper until the wire is eaten completely away. The joint on the ground rod is the most difficult to make and a blow torch furnishes the best method as the rod must be thoroughly heated and of course the surfaces must be perfectly clean.

The Lightning Arrester.—Most manufacturers of telephone instruments for farm lines mount a lightning arrester on the telephone. This is probably done with the idea that, unless the arrester is furnished with the instrument, it may be omitted entirely. It is much better policy to install a separate arrester of an approved type, at a point just at the entrance of the wires to the house, than to depend upon the one furnished with the telephone. There are a number of satisfactory arresters on the market for this purpose. When the telephone line does not run near high voltage electric light and power lines anywhere along its length, a simple lightning arrester without fuses is satisfactory. If power lines are near enough so that a contact between the power and telephone lines would be a

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possibility in case of a break in either wire or a pole on either line, fuses should be provided in addition to the lightning arrester. Where fuses are used the mistake of using too small capacity should not be made. The use of 5 ampere or 7 ampere fuses is recommended and they should be of the enclosed type, that is, the fuse wire should be enclosed in a fibre, porcelain or clay tube. Among the satisfactory types of individual protectors are the following types: Without fuses —Western Electric, No. 60 type; Cook, No. 2 type; Reliable Electric Co., No. 977 A or 977 AA types. With fuses—Western Electric Co., 58 AP type; Cook, No. B-7; Reliable Electric Co., No. 977 B or 977 BB types. These are all standard makes of protector and will be found to be reliable in action.

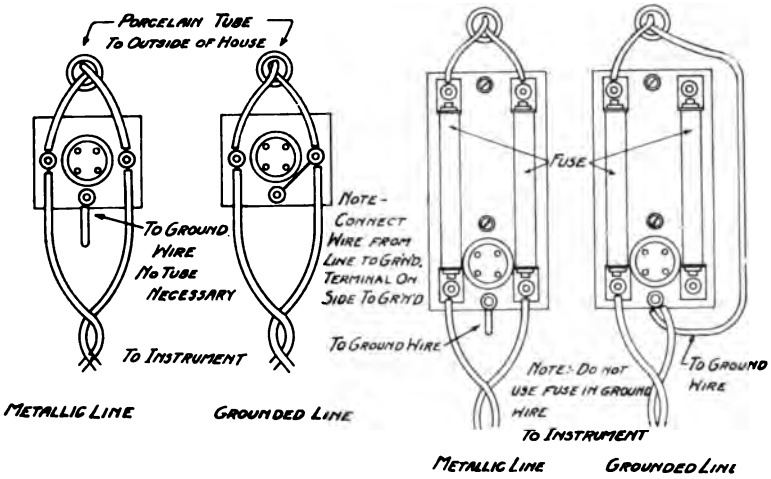


Fig. 4. Method of Connecting Wires to Telephone Protectors.

In mounting the protector, it should preferably be placed about seven feet above the floor. The types which do not have a solid porcelain base covering the entire space under the fuses should be mounted on an asbestos mat. On brick, tile or cement walls a wooden mounting board should be used under the arrester. The method of connecting typical protectors is shown in Fig. 4. All standard types have the binding post terminals marked so that there is no difficulty in identifying the posts to which the various connections should be made.

SUGGESTIONS REGARDING CARE OF THE TELEPHONE

As far as the outside or cabinet of the telephone is concerned, it should be treated as any other piece of furniture. The woodwork should be dusted just as any other piece of wood work ir

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The transmitter, gongs and other nickeled parts may be cleaned with any metal polish that is suitable for use on nickel, care being taken that the polish does not get inside where it may interfere with the working parts. Enameled metal parts such as the transmitter arm, should be cleaned with a cloth just as wood is cleaned. Water should not be used in cleaning the telephone as there is a possibility that the receiver cord or other insulated parts may get wet and trouble result.

If the cabinet is kept tightly closed, little dust will accumulate inside of it and it will seldom be necessary to clean the inside or working parts. However, this may be done occasionally when the batteries are being replaced by wiping off or blowing out the dust.

It seems that in many homes, the telephone is regarded as a sort of an extra shelf and the top becomes the storage place for miscellaneous articles. Many telephone lines have been thrown out of order for hours and even days and telephone repairmen have driven many miles because some one left a pair of metal rimmed spectacles, a metal pencil, a small tool or a tinsel Christmas tree ornament on top of a telephone where it touched the connections and short-circuited or grounded the line. It is best to keep the top of the instrument absolutely clear.

SOME COMMON TELEPHONE TROUBLES AND HOW TO REPAIR THEM

Just as in any piece of machinery, in time wear and use will make repairs to the telephone necessary. Many minor repairs can be made by the owner of the telephone, while some require the services of an expert and still others can only be made in the factory or by a replacement of parts. Space will not permit a full discussion of all of the trouble that may occur and only the more common cases can be mentioned here.

Frequently the telephone is blamed for trouble that really exists on the line. Many perfectly good telephone instruments have been thrown into the junk pile because the lines were not in good working order. *There is no telephone made that will give good service over a line that sags down onto the fences, where the insulators are broken and the wire rests on the poles or cross arms, where trees have grown up around the wire and where the wire itself is full of loop joints or where pieces of barbed fence wire have been spliced into the line after breaks. No telephone in existence will give good service on a grounded line where the ground connection is not good or on any line where unsoldered joints between iron and copper wire are left exposed to the weather.*

In other cases, the telephone is blamed when the trouble is due to failure to use it in the proper manner. Probably the most common

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fault in this respect is failure to talk directly into the transmitter. The telephone transmitter is designed so that the lips must be placed directly in front of the mouthpiece and not over one-half inch away. Yet many times, the telephone is used with the lips of the speaker turned to the side or several inches away. This may be due to location of the instrument in an inconvenient place or it may be due to carelessness. Tests have shown that the effect of talking with the lips a foot from the mouthpiece is just about the same as increasing the length of the line a hundred miles. The proper and improper ways of talking into the telephone are shown in Fig. 5.



Proper Improper

Fig. 5. Proper and Improper Ways of Talking into the Telephone.

Chart for Diagnosing and Locating Trouble.—When trouble actually exists in the instrument, it can be located much more easily if the symptoms are considered and some idea obtained as to which of the parts is likely to be to blame. As an aid, a chart is reproduced from an article by P. Kerr Higgins, in *Telephone Engineer.* While many of the tests described, can only be applied by men familiar with testing instruments, the chart gives a valuable index as to the possible causes and location of the various kinds of trouble. Some of the trouble which may be found in the various parts are described in the following paragraphs.

Transmitter.—The modern types of transmitter seldom cause trouble. When trouble does occur in the transmitter, however, it is

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Diagnosing and Locating Trouble—Possible Location Indicated

SYMPTOMS	Line	Central Office	Arrester	Receiver & Cord	Transmitter	Battery	Hook Switch	Condenser	Induction Coil	Ringer	Generator	Wiring	REMARKS:
1. Can't call or be called	X	X	X									X	Test to see if open, ground or short
2. Can call central but cannot be heard					X	X	X		X				Test for open when subscriber tries to answer
3. Can call central but cannot be called							X	X		X		X	If condenser is in circuit with ringer
4. Can hear but cannot be heard					X	X	X		X			X	
5. Bell does not ring							X	X		X	X	X	Examine springs of generator
6. Line talks up badly	X				X	X			X			X	Test resistance of line with inst. in and out of circuit
7. Can't hear well	X			X					X			X	Test resistance of line with inst. in and out of circuit
8. Noisy line	X	X	X	X	X	X	X		X			X	Test line for resistance and ground
9. Bell rings when not wanted	X			Examine	ground					X			Test line for swinging cross
10. Can be called but cannot hear				X			X		X				
11. Rings others, but own bell weak										X			
12. Open	X	X	X									X	
13. Grounded	X	X	X									X	
14. Short circuit	X	X	X									X	
15. Rings others weakly, receivers O. K.											X	X	
16. Party don't answer	Test line with Voltmeter to see if abnormal												
17. Can't talk to other grounded lines		X		Tip and sleeve reversed			at central office						Test with voltmeter to see which line is wrong
18. Can't call central	X	X	X		Test with Voltmeter								
19. Noisy frying transmitter					X	Poor	or burned carbon (too much battery perhaps)						
20. Cross talk between lines	X	X	X		Examine carbons, also ground connections							X	Test line for insulation

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usually impossible to make repairs in the field. The best plan is to return the part to the manufacturer who is equipped to make any repairs that may be necessary. A common case of trouble in the older types was "packing" or wedging of the carbon grains inside the transmitter. This can be remedied temporarily by tapping (not hammering) the transmitter case but if it is recurring, the only remedy is replacement of the transmitted by a modern type.

Battery.—The battery is the short lived part of the telephone and must be replaced every few months. It is a good plan to place the date on the battery case when new cells are installed; in this way some estimate can be made of their condition. A battery is exhausted whenever damp spots appear on the pasteboard case. In connecting batteries, care should be taken that the connection is made from the carbon or center post of one cell to the zinc or outside post of another. This should always be done with a short piece of insulated wire and the batteries should be so placed in the instrument that the covers are not in contact. The battery should not be blamed for all the trouble in the instrument. Its sole function is to furnish current to the transmitter and it has nothing to do with ringing or receiving rings or with receiving speech.

Receiver.—The moving part of the receiver is a thin flat diaphragm of iron. This diaphragm must be clamped tightly by the receiver cap, must be perfectly flat and must clear the ends of the receiver magnets by a small distance (a few thousandths of an inch). If it is bent so that it touches the magnets or is too far away the receiver will not operate properly. The cost of a new diaphragm is only a few cents and a bent or rusted diaphragm should be replaced by purchasing a new one from the manufacturer of the instrument. Dust or rust sometimes collects on the ends of the magnets and prevents proper vibration. This may be remedied by removing the cap and wiping off the interfering particles. A receiver seldom gives good service with a broken shell or cap, or if the cord is worn or twisted. The manufacturer can supply repair parts in these cases. Lightning sometimes burns out the fine wire of the receiver coils. This may be tested by tapping the terminals of the receiver with wires from one of the dry cells. If clicks are heard the instrument is all right. If no clicks are heard it is probably burned out and must be rewound or replaced. Rewinding can only be done properly in a well equipped repair shop or at the factory.

Induction Coil.—Trouble seldom occurs in the induction coil except that the windings are sometimes burned out by lightning. It is impracticable to make repairs anywhere but in a regular repair shop or factory. In taking out and replacing the induction coil it is necessary to use extreme care to see that it

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when replaced. Primary and secondary terminals are marked on the spool heads and tags placed on the wires will aid in identifying them.

Generator.—The generator does not require frequent attention. A drop or two of a good light oil such as is used for guns, clocks or sewing machines, placed in the oil holes will keep the bearings lubricated for months. If the winding should be burned out by lightning, it can only be repaired where rewinding facilities are available.

Ringer.—There are two adjustments of the ringer that sometimes have to be made. One is the adjustment of the distance between the pivoted bar, or armature as it is called, and the pole pieces. The manner in which this adjustment is made is different in different types of ringers and no rule can be given for doing it. It will be evident from an examination of the ringer as all the parts are in sight. The other adjustment is that of the gongs. The gongs should be set just far enough apart so that the striker will not touch them when pushed over by the fingers. When the ring comes in, the striker rod will spring enough to allow the head to strike the gongs and then spring away without deadening the vibration.

In some of the older types of ringers, trouble due to the sticking of the armature to the pole pieces sometimes occurs. This may be due to worn or tight pivots or to the fact that the pole pieces (projecting ends of the iron cores of the spools) have become permanently magnetized. If the trouble is chronic the latter is probably the cause and the only remedy is replacement. This trouble is avoided in modern types by proper design and the use of suitable materials.

Condenser.—The condenser seldom gives trouble except in the rare cases when it is burned out by lightning. The only remedy is replacement.

Lightning Arrester.—Trouble at the lightning arrester is usually due to the deposit of carbon dust between the line and ground plates. It is a good thing to remove the carbon plates after a thunder storm and brush off the surface with a piece of soft cloth. They should never be scraped with a knife as this increases the distance between the blocks and the protection afforded is reduced. The original mica or other insulating separator should be used and no additional separation should be given between the carbon and the ground plates. Modern types of lightning discharge blocks such as furnished with the arresters recommended above seldom give trouble or require cleaning.

If fuses are blown, they should be replaced by new ones. It is well to keep a few spare fuses on hand for this purpose.

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Circulars

*CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

CIRCULAR No. 3. Hints on Automobile Maintenance, by H. A. Huebotter, 1924.

CIRCULAR No. 4. Operation of Three Phase Induction Motors Under Abnormal Supply Conditions, by D. D. Ewing and C. F. Bowman.

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FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

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OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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BULLETIN OF
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PUBLICATIONS OF THE ENGINEERING DEPARTMENTS

Comparative Accuracy of Three-Phase, Four-Wire Metering Methods

D. T. CANFIELD

BULLETIN NO. 15
ENGINEERING EXTENSION DEPARTMENT
LAFAYETTE, INDIANA

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BULLETIN NO. 13
ENGINEERING EXTENSION DEPARTMENT

Comparative Accuracy of Three-Phase, Four-Wire Metering Methods

By
D. T. CANFIELD
Instructor in Electrical Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
DECEMBER, 1925

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Comparative Accuracy of Three-Phase, Four-Wire Metering Methods

INTRODUCTION

The three-phase, four-wire system of distribution was first used commercially about twenty-five years ago, and immediately attained considerable popularity in foreign countries. Its adoption in this country, however, has been rather slow in the past, but it is now becoming more nearly universal, as several distinct advantages result from its use.

First, higher line to line voltages are possible for the same distributing transformers; second, economy in copper results as the load factor of the circuit can be kept higher, since both lighting and power may be fed from the same circuit; and third, the evils resulting from unbalancing in three-phase, three-wire systems are effectively reduced in the four-wire system, as the unbalanced currents are carried in the fourth or neutral wire.

However the adoption of this system immediately gave rise to a metering problem considerably more complicated than that of the three-wire system. To meet this situation several metering methods or combinations have been proposed from time to time. It is the purpose of this Bulletin to discuss these methods and to give the results of a study that was made of the comparative accuracy of these various metering methods. The experimental work was done by Messrs. E. W. Ritter and M. L. Potter, Jr., of the Class of 1925, under the supervision of the writer.

The methods investigated were the following:

1. The three-wattmeter method, Fig. 1.
2. The two-wattmeter method, Fig. 2.
3. The four-wire wattmeter method, using a third current element, Fig. 3.
4. The two element polyphase wattmeter method, using two potential and three current transformers, Fig. 4.
5. The two element polyphase wattmeter method, using three potential and three current transformers, Fig. 5.

Part I of this Bulletin discusses the theory of each of these methods and the reasons for and against their use.

Part II describes the tests that were made, and draws conclusions therefrom concerning the relative accuracy of each method.

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PART I

A THEORETICAL DISCUSSION OF EACH METHOD

It is well understood that, in general, there will be required one less complete wattmeter than there are wires, in any three-phase distribution system, to measure correctly the power being consumed therein. Thus in the four-wire system, there would theoretically be required three complete wattmeters or their equivalent to measure correctly the power.

A brief theoretical discussion of the application of this principle to each of the methods enumerated above will now be given, together with some of the practical reasons for and against its adoption, in order to show wherein a given method is or is not an equivalent.

METHOD 1

Three-Wattmeter Method

Assuming sine wave quantities and symmetrical voltages and currents, we have the relations existing in Fig. 6 (a) where E_a, E_b, E_c are the line to neutral voltages of the three phases and I_a, I_b, I_c are the line currents which may or may not be in phase with their voltages. To take the most general case, assume each to lag its voltage by the angles α, β, and Υ respectively. Then the general expression for the power in each phase will be,

(1) $P_a = E_a I_a \cos \alpha$, where $I_a \cos \alpha$ is the power component of the current in the top current coil.

(2) $P_b = E_b I_b \cos \beta$.

(3) $P_c = E_c I_c \cos \Upsilon$.

From fundamental principles the total power will be the sum of the power in the separate phases or,

(4) $P_{abc} = E_a I_a \cos \alpha + E_b I_b \cos \beta + E_c I_c \cos \Upsilon$.

In the balanced condition assumed, $E_a = E_b = E_c = E$, $I_a = I_b = I_c = I$ and $\alpha = \beta = \Upsilon = \Theta$.

Therefore equation (4) becomes (5) $P_{abc} = 3\ EI \cos \Theta$ where E is the line to neutral voltage, I the line current, and $\cos \Theta$ is the power factor.

It is evident that three-wattmeters connected as in Fig. 1 will record respectively the quantities expressed in equations (1), (2), and (3), and that the sum of their registrations will record the quantity expressed in equation (4). Since each wattmeter is a complete and independent unit, it makes no difference whether the voltages and currents are equal or different, nor do the angles have to be the same. In other words, the deflection of wattmeter No. 1 is still pro-

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portional to the product of E_a, I_a, and cos a, no matter what the individual values of these quantities are, and whether or not they are equal to or different from the corresponding quantities in the other phases.

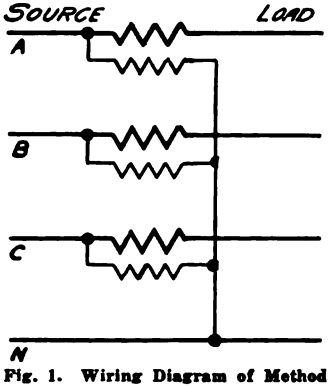


Fig. 1. Wiring Diagram of Method 1.

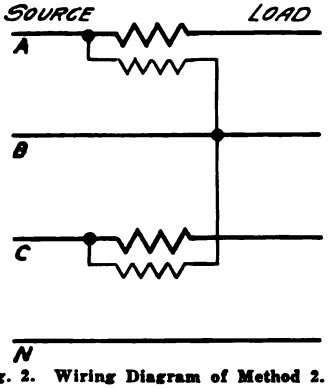


Fig. 2. Wiring Diagram of Method 2.

Thus Method 1 will record the true power under any condition of balance or unbalance, assuming each wattmeter to be properly calibrated in itself. For this reason Method I offers a good standard for comparison, and was the one used in Part II of this Bulletin for that purpose.

Although theoretically accurate, this method has met with some opposition in commercial practice because of the expense of the additional wattmeter and the necessity of reading and adding three separate registrations. Today this latter objection is not so important, as there are on the market three-element totalizing wattmeters.

METHOD 2

Two-Wattmeter Method

This method, which theoretically stands at the other end of the accuracy list, was included here simply to show that, except in the one case of virtually perfect balance, it can not be used for even an approximation of the power consumed in a four-wire system.

Although this is the best known and most universally used power measuring scheme for polyphase circuits, and therefore has a strong appeal to the average meterman, it is out of the question from the standpoint of accuracy.

As an illustration, take the extreme case of a load connected from line b to neutral only, Fig. 2. However large this load might be, nothing whatever would be recorded on the wattmeter.

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METHOD 3

Four-Wire Wattmeter Method

The four-wire polyphase meter shown in Fig. 3 has four equal current coils, two on each element of the meter. Coils 2 and 3 are wound in the reverse direction to 1 and 4 respectively, and connected in series with each other and that line wire to which no potential lead is attached. The effect of this is to reverse the vector I_b of Fig. 6(a), so that it makes the angle $(60 - \beta)$ with E_a and $(60 + \beta)$ with E_c. The part of this current which is effective in producing torque in the meter in each case is $I_b \cos (60 - \beta)$ and $I_b \cos (60 + \beta)$. The power equation of the meter will then be,

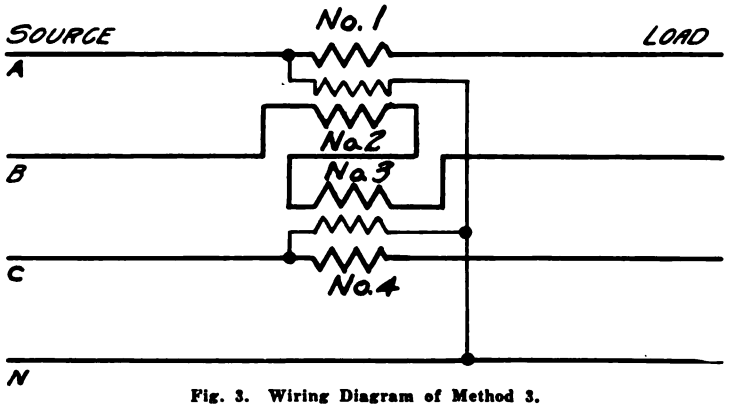


Fig. 3. Wiring Diagram of Method 3.

(6) $P_{abc} = E_a I_a \cos \alpha + E_a I_b \cos (60 - \beta) + E_c I_b \cos (60 + \beta) + E_c I_c \cos \Upsilon$.

By well known trigonometric formulas, equation (6) may be put in the following form,

(7) $P_{abc} = E_a I_a \cos \alpha + \frac{1}{2} I_b (E_a + E_c) \cos \beta + E_c I_c \cos \Upsilon$.

In the case of balanced voltages assumed, $E_a + E_c$ is numerically equal to 2 E_b, therefore equation (7) becomes $P_{abc} = E_a I_a \cos \alpha + E_b I_b \cos \beta + E_c I_c \cos \Upsilon$, which is identical with equation (4) for the three-wattmeter method.

This principle is shown graphically in Fig. 6 (a) by the dotted vectors. Here I_b reversed lags the vector sum of E_a and E_c by the same angle β that I_b lagged E_b.

The vector sum of E_a and E_c is equal and opposite to E_b, and it is evident that the combination that is effective in producing torque is $(E_a + E_c)(-I_b \cos \beta) = -E_b \times -I_b \cos \beta = E_b I_b \cos \beta$.

It is also obvious from an inspection of this Fig. 6 (a), that the above proof is based on a balanced symmetrical system. Therefore

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any unbalancing of the voltages will spoil this symmetry and thereby introduce an error in the registration of the meter.

Supposing, for example, that an excess, in phase current flows in line b to which no potential lead is attached. This will cause a greater drop in line b than in either line a or c, and also a drop in the neutral because this excess current returns to the source through the neutral.

This latter drop will cause the neutral point to shift along that voltage vector in which the excess current existed. These two effects are shown in Fig. 6 (b), where the excess drop in the line b is equal to LP and the drop in the neutral due to the excess current in line b is equal to NO.

The meter should read the voltage E_b = PN but as seen in equation (7) above it actually reads $E_a + E_c$ = NQ = NO + OM + MQ. Since NRQS and ORMS are parallelograms, NO = MQ, and as OM and OL are radii of the same circle OM = LP + PN + NO. Making these substitutions we get $E_a + E_c$ = NO + LP + PN + NO + NO = PN + LP + 3 NO.

Therefore the error introduced in the registration of phase b is LP + 3 NO. This means that the error is equal to the excess drop in the line b plus 3 times the drop in the neutral. For the particular case shown in Fig. 6 (b) the cross section of the neutral is assumed to be the same as the line wires so that LP = NO.

If the excess in phase current had occurred in one of the lines to which a potential lead is attached, such as line C, it will produce the effect shown in Fig. 6 (c). In this figure NR is the resultant of E_a and E_c.

This vector NR should be equal and opposite to E_b or equal to NQ if the meter is to record correctly the power consumed in phase b. We see, however, that in addition to a difference in magnitude there is a difference in position. Each of these differences will produce an error in the registration of the meter.

The problem of calculating these two errors becomes very complicated especially on inductive loads, as then the excess drops will no longer be in phase with the voltages. For an approximate relation the reader is referred to a paper by Mr. G. W. Stubbins* who points out that the unbalances customarily met in commercial practice probably are not of sufficient magniture to cause appreciable errors except at low power factors.

The chief objection to this method by metermen seems to be that it is a special meter, requiring special testing methods with which they are not as familiar as with those for the two wire meter.

*G. W. Stubbins, London Electrician. Vol. 87, Dec. 16, 1921. Page 754-5.

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METHOD 4

Two-Element Polyphase Wattmeter Method

The same principle discussed in Method 3 may be applied by using three current transformers connected in a closed delta on the secondary side, and by using the ordinary polyphase meter as shown in Fig. 4.

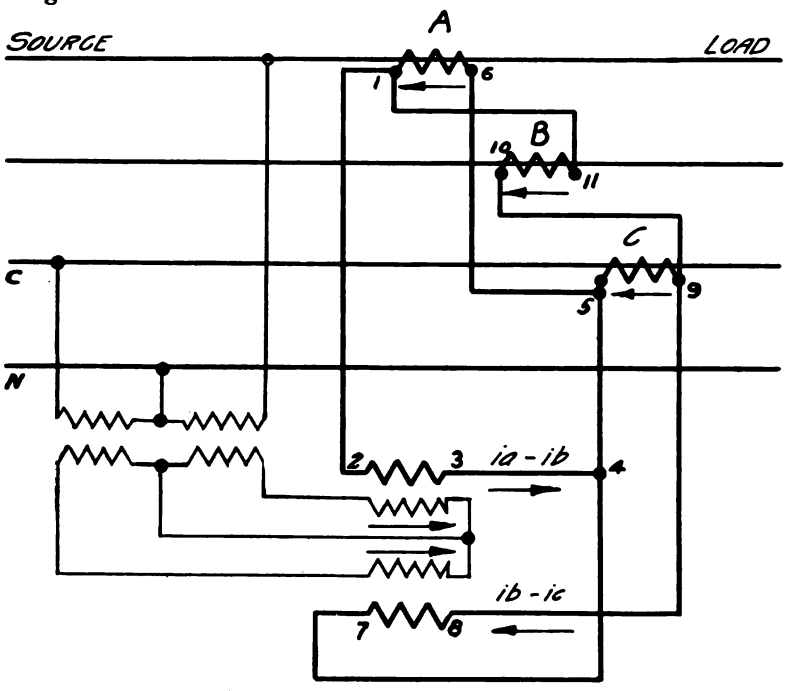


Fig. 4. Wiring Diagram of Method 4.

If the current transformers are properly connected the current i_a from transformer A will flow from 1-2-3-4-5-6, the current i_c from transformer C will flow from 5-4-7-8-9, and the current i_b from transformer B will flow from 10-9-8-7-4-3-2-1-11. Thus this current i_b circulates through both elements and therefore reacts with both voltage elements exactly as it did in the four-wire meter of Method 3.

The top current coil will have in it a resultant current $(i_a - i_c)$ flowing in the same direction as the voltage in the top voltage coil.

The bottom current coil will have in it a resultant current $(i_b - i_a)$ flowing in the reverse direction to the voltage. This produces the same torque as a current $-(i_b - i_c)$ or $(i_c - i_b)$ flowing in the same direction as the voltage.

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The phase relations of these currents and voltages are shown in Fig. 6 (d). From this figure we see that the current $(I_b - I_c)$ reversed is $(I_c - I_b)$ and that as far as the meter is concerned the relations are the same as those of Fig. 6 (a).

Taking each component of the resultant current in each element separately we can write the power equation of this combination as before, where $P_{abc} = E_a I_a \cos \alpha + E_a I_b \cos (60 - \beta) + E_c I_b \cos (60 + \beta) + E_c I_c \cos \Upsilon$. As previously shown, this equation is equal to $E_a I_a \cos \alpha + E_b I_b \cos \beta + E_c I_c \cos \Upsilon$.

Using the notation of equation (5) and Fig. 6 (d) we can work out a proof using the resultant currents as follows. The top element current is $(I_a - I_b) = \sqrt{3}\, I_a = \sqrt{3} I$. This current is out of phase with the voltage $E_a = E$ in this element by the angle $(30 - \alpha) = (30 - \Theta)$. That part of the power measured by the top element is then $\sqrt{3}\, EI \cos (30 - \Theta)$.

The bottom element current is $(I_c - I_b) = \sqrt{3}\, I_c = \sqrt{3}\, I$. This current is out of phase with the voltage $E_c = E$ in this element by the angle $(30 + \Upsilon) = (30 + \Theta)$. That part of the power measured by the bottom element is then $\sqrt{3} EI \cos (30 + \Theta)$.

The total power is

$$\begin{aligned} P_{abc} &= \sqrt{3}\, EI \cos (30 - \Theta) + \sqrt{3}\, EI \cos (30 + \Theta). \\ &= \sqrt{3}\, EI \left[\cos (30 - \Theta) + \cos (30 + \Theta)\right]. \\ &= \sqrt{3}\, EI \left(\frac{2\sqrt{3}}{2} \cos \Theta\right) \\ &= 3\, EI \cos \Theta. \end{aligned}$$

It is obvious that this Method is subject to the same inherent errors as Method 3, and needs no further elaboration. The principal advantage of this method is that it uses standard apparatus normally kept on hand, and familiar to all metermen. On the other hand, some difficulty is experienced in getting the three current transformers connected in the circuit properly, so that none is reversed. One other point in connection with this method is, that current transformers must always be used regardless of the actual capacity of the load to be measured.

METHOD 5

Two-Element Polyphase Wattmeter Method with Three Voltage Transformers

This method is identical in theory with Method 4, but varies from it physically in having an extra voltage transformer, so connected as to form a closed delta on the secondary side. Since open delta power transformers have an inherent voltage unbalance and also produce a phase angle error at low power factors it was thought that open

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delta voltage transformers might produce a similar effect. It has been suggested that by closing the delta with a third voltage transformer these difficulties would be eliminated. Also it was thought that circulating currents might tend to reduce the effect of primary voltage unbalance upon the meter.

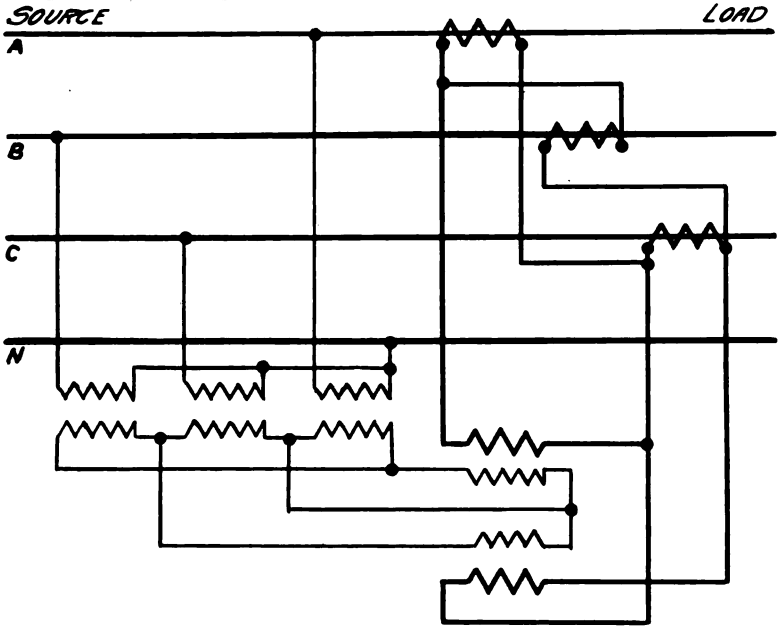


Fig. 5. Wiring Diagram of Method 5.

In order to test this out Method 5 was included in the tests, although the arrangement is not in as common use as the other methods.

PART II

EXPERIMENTAL DETERMINATION OF COMPARATIVE ACCURACY OF THE METHODS INVESTIGATED

Pertinent to any discussion of meter accuracy is the question of the magnitude of the errors existing under practical conditions. But when the answer to this question depends upon the magnitude and distribution of the unbalancing among the several phases, as it does here, a complete answer is impossible, as there are evidently an infinite number of such conditions.

We are, therefore, forced to confine ourselves, at the outset, to a representative set of conditions, drawing therefrom as many general conclusions as seem legitimate.

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Data for this work were obtained by comparing Methods 2 to 5 inclusive with Method 1. This was done by putting the current elements of all methods in series with a common non-inductive load, so regulated that the current flowing in any wire could be readily varied. The potential elements were arranged in parallel, and a phase shifter was used in order to obtain any desired power factor, lagging or leading. This circuit is shown in Fig. 7.

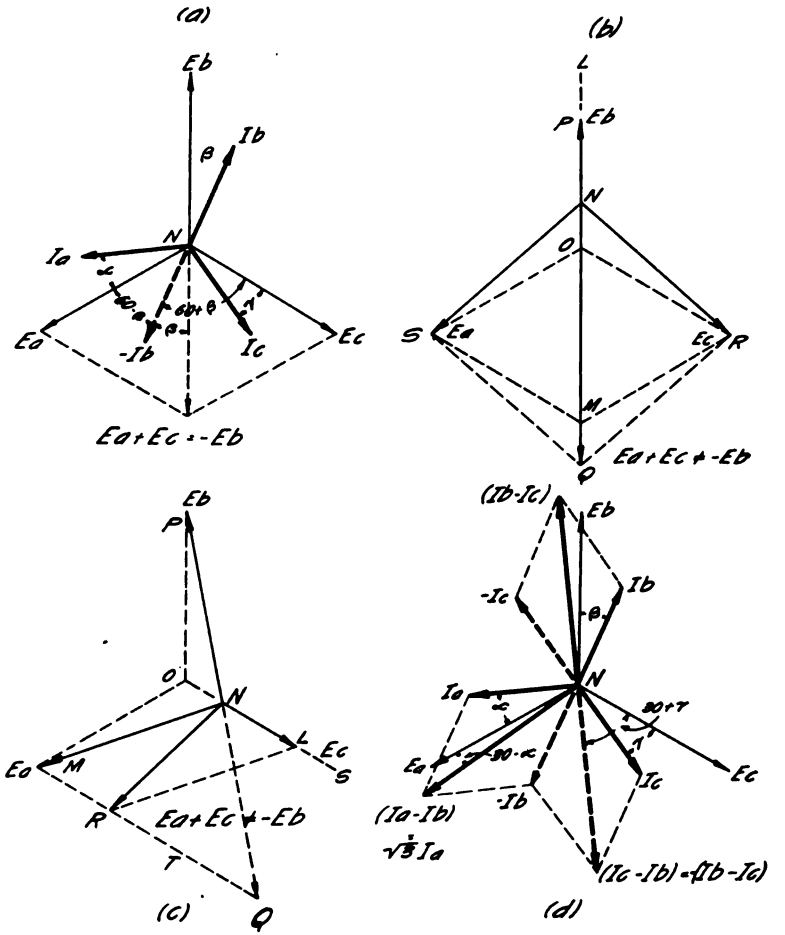


Fig. 6. Vector Diagrams Illustrating Three-Phase, Four-Wire Power Measurement.

Power was supplied at 110 volts and 60 cycles from a sine wave alternator, with provision for inserting a constant resistance in each main lead, when unbalanced voltages were desired.

The settings of the phase shifter were determined under balanced

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conditions for 100 per cent, 85 per cent, 75 per cent, and 50 per cent leading and lagging power factors and always turned to these settings for the corresponding power factors on unbalanced conditions.

For each condition of balance or unbalance seven complete determinations were recorded, one for each of the seven power factors. Thus in Tables I and II, each test represents seven determinations all at different power factors.

Columns 2 to 7 inclusive of both tables give the approximate combinations of unbalances that were decided upon as covering all the necessary conditions.

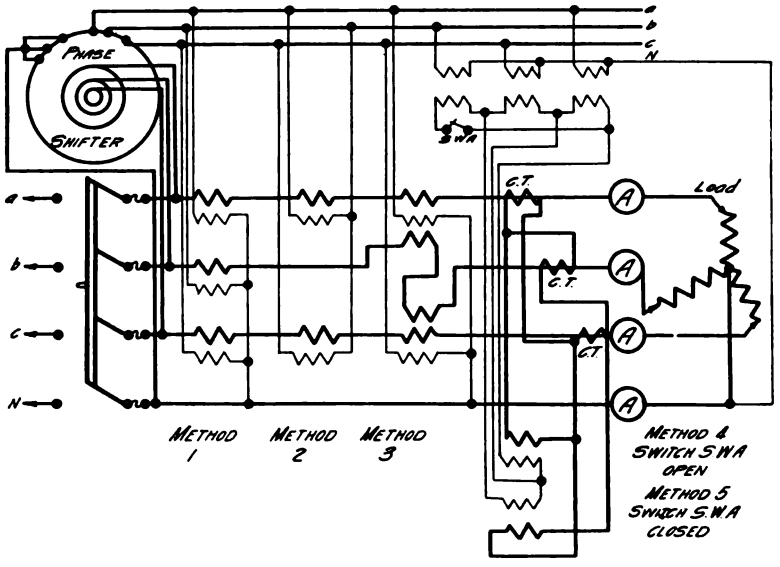


Fig. 7. Wiring Diagram of Circuit Used.

The twelve columns under the heading Percent Error in Table I give in condensed form the results of the tests. The columns maximum fast and maximum slow are here used to mean the extreme fast error and the extreme slow error. The average fast and average slow columns give the numerical average of the fast or plus errors and the minus or negative errors. The number of determinations averaged to determine the average fast and average slow columns is placed to the left of the division line in bold face type. Since there were seven determinations for each test, one for each power factor, the sum of these numbers should equal seven. If they do not, as in Test 4, Method 3, the difference is the number of readings in which the method in question gave a correct indication of the power

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TABLE I.—THREE PHASE FOUR-WIRE METERING 100-85-75-50 LAGGING AND LEADING POWER FACTOR.

Test No.	Per Cent of Full Load						PER CENT ERROR								
							METHOD 2				METHOD 3				METHODS 4 AND 5			
	Currents			Voltage			Max. Fast	Average		Max. Slow	Max. Fast	Average		Max. Slow	Max. Fast	Average		Max. Slow
	PhA	PhB	PhC	PhA	PhB	PhC		Fast	Slow			Fast	Slow			Fast	Slow	
1	100	100	100	100	100	100	3.90+	6/1.41	1/0.18	0.18—	4.36+	3/2.45	4/1.79	3.34—	8.55+	7/4.38	0/0	0.98+
2	60	80	100	100	100	100	28.20+	4/12.60	3/14.70	42.50—	3.25+	3/1.93	4/1.70	3.30—	12.40+	7/6.25	0/0	2.12+
3	80	100	60	100	100	100	9.82+	1/9.82	6/12.90	21.82—	2.48+	3/1.54	4/1.41	1.96—	12.20+	7/6.40	0/0	3.06+
4	100	60	80	100	100	100	29.00+	7/15.42	0/0	2.08+	0.98+	3/0.58	3/1.00	1.64—	12.40+	6/6.27	1/8.70	8.70—
5	0	100	100	100	100	100	51.70+	3/25.23	4/60.37	100 00—	8.03+	4/2.51	3/2.01	5.10—	16.40+	6/8.23	1/0.46	0.46—
6	100	0	100	100	100	100	62.00+	6/51.30	0/0	000	3.61+	4/1.42	3/1.14	2.30—	7.24+	7/4.23	0/0	1.59+
7	100	100	0	100	100	100	54.70+	2/36.80	5/49.50	100.00—	4.35+	4/2.25	2/0.64	0.95—	13.20+	6/5.98	0/0	000
8	0	60	100	100	100	100	95.00+	3/58.60	4/52.09	100.00—	15.21+	3/5.84	3/1.58	2.66—	12.30+	7/6.41	0/0	4.10+
9	100	0	60	100	100	100	91.60+	6/62.10	1/23.80	23.80—	3 13+	2/1.66	5/1.80	4.15—	5.12+	6/3.14	1/3.36	3.36—
10	60	100	0	100	100	100	17.00+	1/17.00	6/55.20	100.00—	5.94+	4/2.11	3/2.57	3.94—	8.95+	6/4.37	0/0	000
11	100	0	0	100	100	100	284.00+	5/130.77	2/55.20	87.00—	11.30—	0/0	7/4.54	1.31—	4.17+	5/3.27	0/0	000
12	0	100	0	100	100	100	100.00—	0/0	7/100.00	100.00—	9.42—	0/0	7/5.60	2.33—	20.60+	6/9.19	1/5.23	5.23—
13	0	0	100	100	100	100	183.00+	4/126.60	3/51.10	100.00—	10.70—	0/0	7/4.94	1.24—	12.60+	7/10.39	0/0	7.35+
14	100	80	100	100	95	110	12.10+	6/7.06	1/15.50	15.50—	3.29+	5/1.40	2/0.69	0.89—	8.03+	7/4.52	0/0	1.98+
15	80	100	100	95	110	100	6.91+	3/4.10	4/11 10	17.80—	3.02+	4/2 13	2/5.37	10.10—	8.32+	6/4.69	1/5.50	5.50—
16	100	100	80	110	100	95	12.71+	3/5.61	4/11.61	23.60—	15.50+	6/4.81	1/12.70	12.70—	15.20+	6/6.87	1/0.41	0.41—
17	0	100	80	100	95	110	38.90+	1/38.90	6/59.50	100.00—	1.84+	2/1.49	5/2.17	4.77—	16.30+	6/8.32	1/0.80	0.80—
18	80	0	100	95	110	100	129.00+	7/58.50	0/0	32.60+	2.54+	2/1.35	5/4.24	9.76—	6 33+	6/4.33	1/3.89	3.89—
19	100	80	0	110	100	95	83.40+	3/41.90	4/62.30	100.00—	2.72+	4/1.41	2/2.48	3.02—	11.65+	4/5.32	3/1.73	4.05—

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TABLE II.—ORDER OF BEST PERFORMANCE OF THREE PHASE FOUR-WIRE METERING METHODS.

Test No.	Per Cent of Full Load						Methods Arranged in Order of Greatest Accuracy
	Currents			Voltage			
	PhA	PhB	PhC	PhA	PhB	PhC	
1	100	100	100	100	100	100	2, 3, (4 & 5)
2	60	80	100	100	100	100	3, (4 & 5), 2
3	80	100	60	100	100	100	3, (4 & 5), 2
4	100	60	80	100	100	100	3, (4 & 5), 2
5	0	100	100	100	100	100	3, (4 & 5), 2
6	100	0	100	100	100	100	3, (4 & 5), 2
7	100	100	0	100	100	100	3, (4 & 5), 2
8	0	60	100	100	100	100	3, (4 & 5), 2
9	100	0	60	100	100	100	3, (4 & 5), 2
10	60	100	0	100	100	100	(4 & 5), 3, 2
11	100	0	0	100	100	100	(4 & 5), 3, 2
12	0	100	0	100	100	100	3, (4 & 5), 2
13	0	0	100	100	100	100	3, (4 & 5), 2
14	100	80	100	100	95	110	3, (4 & 5), 2
15	80	100	100	95	110	100	3, (4 & 5), 2
16	100	100	80	110	100	95	(4 & 5), 3, 2
17	0	100	80	100	95	110	3, (4 & 5), 2
18	80	0	100	95	110	100	3, (4 & 5), 2
19	100	80	0	110	100	95	3, (4 & 5) 2

in the circuit. If a method showed all determinations high the symbol 0/0 appears in the average slow column. If the lowest reading a given method gave happened to be a correct indication of the power in the circuit, the symbol 000 will appear in the maximum slow column. If the meter stopped or read zero for actual consumption of power the symbol 100.0— appears in the maximum slow column.

The last column of Table II gives the order of best performance of the several methods. It was deduced from a study of the average fast and slow columns of Table I. Except for a few close decisions the order is obvious. For these a little study of the relative magnitudes will show a balance in favor of the order shown.

CONCLUSION

After a study of Table I, together with the individual tests, data for which are not included, we may safely say that for all ordinary conditions the three-phase, four-wire meter of Method 3 gave results that are comparable with the Standard Method 1. In fact, the two methods checked so closely at times, that no appreciable error was noticed. It must be remembered, however, that this method was used without instrument transformers, and that any error due to them is absent.

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As was predicted, Method 2 was very inaccurate except in test 1 where balanced conditions existed.

The results of Methods 4 and 5 were identical in all tests and were, on the average, somewhat higher than the standard method. Part of this was undoubtedly due to errors in the instrument transformers, as the meter itself was carefully checked against the standard, and found to be correct. These two methods, under practically all conditions of load, power factor, and voltage gave results that are next in order to Method 3. In a few instances, such as balanced two phase loads and voltages, and single phase loads, these results were better than those of Method 3 on leading power factors. This fact may be due to the transformers having a lagging phase angle error and because of the leading power factor loads, this lagging phase angle error helps to make the meter readings more accurate. However, this would have the reverse effect on lagging power factors.

It therefore seems safe to recommend,

First, that Method 2 is hopelessly inaccurate and should never be used.

Second, that since Method 5 did not show any improvement over Method 4 under any of the conditions of the test, it therefore in no way justifies the additional expense and complications of the third voltage transformer.

Third, that without instrument transformers, Method 3 is slightly better on the average than Method 4.

Fourth, that with instrument transformers, Method 4 is probably equally as good as Method 3.

Fifth, that for very accurate metering Method 1 must be used.

Sixth, that for the measurement of large amounts of energy, where even a slight increase in precision quickly amounts to appreciable savings, Method 1 is strongly recommended especially if any appreciable voltage unbalance is likely to occur or where the power factor is liable to be low.

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PUBLICATIONS OF THE ENGINEERING EXTENSION SERVICE

Circulars

*CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

CIRCULAR No. 3. Hints on Automobile Maintenance, by H. A. Huebotter, 1924.

CIRCULAR No. 4. Operation of Three Phase Induction Motors Under Abnormal Supply Conditions, by D. D. Ewing and C. F. Bowman.

CIRCULAR No. 5. Publications of Engineering Experiment Station and Engineering Extension Service.

CIRCULAR No. 6. Why Our Road Maintenance Costs are Increased so Rapidly, by Ben H. Petty, 1924.

CIRCULAR No. 7. Road Law Procedure in the State of Indiana, by E. L. Arnold, 1925.

Bulletins

BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright, 1922.

BULLETIN No. 2. House Construction that Reduces Heating Costs, by James D. Hoffman, 1923.

BULLETIN No. 3. Pictorial Description of Engineering Activities, Purdue University, 1923.

BULLETIN No. 4. Electric House Pumping Systems, by G. C. Blalock and D. D. Ewing, 1923.

BULLETIN No. 5. Proceedings of the Tenth Annual Road School, by Ben H. Petty, 1924.

BULLETIN No. 6. Proceedings of the Second Annual Conference of Indiana Foundrymen, by J. P. Walsted, 1924.

BULLETIN No. 7. Thawing Water Pipes with Electric Current, by D. D. Ewing and C. F. Bowman, 1924.

BULLETIN No. 8. Connection Checks for Polyphase Watthour Meters, by D. T. Canfield, 1924.

BULLETIN No. 9. Reconstruction of Old Gravel Roads, by C. C. Albright and R. E. Mills, 1925.

BULLETIN No. 10. Proceedings of Eleventh Annual Road School, by Ben H. Petty, 1924.

BULLETIN No. 11. A City Planning Primer, by G. E. Lommel and F. G. Bates, 1925.

BULLETIN No. 12. Care of Farm House Telephone, by R. V. Achatz, 1925.

BULLETIN No. 13. Comparative Accuracy of Three-Phase Four-Wire Metering Methods, by D. T. Canfield, 1925.

Mimeographs

The following material has been issued in mimeograph form:

FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

* Out of print.

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BULLETIN OF
PURDUE UNIVERSITY
PUBLICATIONS OF THE ENGINEERING DEPARTMENTS

VOL. X MARCH, 1926 NO. 2

Proceedings
Twelfth Annual Road School

Held at

PURDUE UNIVERSITY

Compiled and Edited by

BEN H. PETTY

BULLETIN NO. 14

ENGINEERING EXTENSION DEPARTMENT
LAFAYETTE, INDIANA

Published by Purdue University at LaFayette, Indiana
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THE ENGINEERING EXTENSION DEPARTMENT OF PURDUE UNIVERSITY

Purdue University recognizes its opportunity for public service by carrying the benefits of its teaching and research activities to those in the State who are interested in engineering problems, but who are unable to be benefited by the regular courses of resident instruction which are offered at the University.

The Engineering Extension Service at Purdue University is carried on in the following ways:

1. Conferences are held at Purdue University and at other places in Indiana for the benefit of road builders, canners, electrical workers, power plant men, foundrymen and for others engaged in manufacturing and in public utility industries.

2. Groups of lectures are delivered by engineering experts of Purdue University for the benefit of industrial workers and executives. Talks are also given on subjects related to engineering before civic, commercial and manufacturing organizations.

3. Publications in the form of bulletins and circulars are issued containing up-to-date information on engineering subjects.

Address communications concerning Engineering Extension Service to

DIRECTOR OF ENGINEERING EXTENSION DEPARTMENT,
Purdue University, Lafayette, Indiana.

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BULLETIN NO. 14
ENGINEERING EXTENSION DEPARTMENT

Proceedings

of the

Twelfth Annual Road School

held at

PURDUE UNIVERSITY

January 18 to 22, 1926

Under the Direction of
THE SCHOOL OF CIVIL ENGINEERING
With the Co-operation of
The Indiana State Highway Commission,
The Indiana County Highway Superintendents' Association,
The Indiana County Surveyors' and County Engineers' Association,
and
The City Street Commissioners' Association
of the State of Indiana.

Compiled and edited by Ben H. Petty,
Assistant Professor of Highway Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
MARCH, 1926

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PREFACE

This year's Road School has excelled all previous attempts, not only in attendance, but also in the value of the very practical program. This success is due primarily to the splendid co-operation on the part of the interested Purdue Officials, and also the three major co-operating organizations.

The classified registration was as follows:

State Highway Officials	58
County Highway Superintendents	82
Asst. County Highway Superintendents	15
County Surveyors	75
Deputy County Surveyors	5
County Commissioners	19
City Officials	30
Contractors	17
Materials and Equipment men	82
Miscellaneous	52
Total	435

The total registration was practically the same as that of last year.

This year the County Surveyors were compelled, for the first time, to attend by law, and, as a result, we had an attendance of seventy-five from this group. The counties whose surveyors failed to attend the Road School are as follows:

Brown	Jennings	Ohio	Spencer
Decatur	Johnson	Owen	Switzerland
Floyd	Martin	Perry	Union
Harrison	Monroe	Posey	Wells

Eighty-two County Highway Superintendents were present. The missing counties being:

Brown	LaGrange	Perry	Sullivan
Crawford	Orange	Spencer	Vigo
Dubois	Owen		

The four-year term of office for County Highway Superintendents ended December 31, 1925, and as a result there were many new men at the school this year. Fifty-two of the ninety-two Highway Superintendents are new this year. This represents a turnover of 56.5%.

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Only two new county surveyors took office this year.

The Dinner-Smoker held on Monday evening in the Union Building was attended by 212 men which is practically 100 more than attended a similar event last year. Mr. Harry Leslie, Speaker of the House, Indiana State Legislature, and Mr. R. M. Southworth, Indiana State Senator, were the principal speakers. The members of the Contour Society, (honorary Civil Engineering society), co-operated splendidly in providing entertainment for this affair and the entire membership attended.

The annual banquet held on Thursday evening in the Union Building was undoubtedly the best affair of its kind ever held at Purdue. There were 357 men present and splendid addresses were made by Dr. W. K. Hatt, as toastmaster, President E. C. Elliott, of the University and Mr. John Brown, chairman of the Indiana State Tax Commission. Due to the serious illness of his wife, Governor Jackson was unable to be present at the banquet as he had planned, and Mr. Brown was sent as his representative. An interesting innovation at the banquet was the broadcasting of the orchestra music and the addresses of the evening. This was made possible through the courtesy of the School of Electrical Engineering with Mr. Harry Clark announcing.

The old officers of the County Highway Superintendents' Association worked up a banquet (rather on the spur of the moment) which was held in the roof garden of the Fowler Hotel, Wednesday evening. The invited guests included Dr. Hatt, Professors Eriksen, Knapp, Petty and Leister, Mr. H. G. Leslie and Mr. Fred Connell. President Elliott was unable to be present.

The new officials elected by the co-operating associations are as follows:

COUNTY HIGHWAY SUPERINTENDENTS' ASSOCIATION

Matt Foster, Evansville.....President
Wm. Tonkel, Ft. Wayne.....Vice-President
Fred Hubbell, Angola.....Secretary-Treasurer

COUNTY SURVEYORS' ASSOCIATION

Don Heaton, Fowler.....President
R. W. Meisinger, Evansville.....Vice-President
C. K. Wallace, East Chicago....Secretary-Treasurer

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CITY STREET COMMISSIONERS' ASSOCIATION

A. A. Girton, Shelbyville.....President
Charles Buck, Madison.....Vice-President
H. H. Blunk, Martinsville.....Secretary
W. M. Williams, Newcastle.....Treasurer

This year, for the first time, we provided for separate sessions of the different groups during the last day of the School. This proved highly satisfactory and more time will be allotted to these separate sessions in future Schools.

March 1, 1926. B. H. P.

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PROGRAM

(Meetings held in Room 101 Civil Engineering Building except as noted)

MONDAY, JANUARY 18th

Morning

Registration at Civil Engineering Building.

Afternoon

Presiding—Prof. W. A. Knapp, Professor in Charge, Engineering Extension Department, Purdue University.

Address of Welcome—
Professor W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Replies—
Mr. George E. Hershman, Member, Indiana State Highway Commission.
Mr. W. O. Jones, President, Indiana County Highway Superintendents' Association.
Mr. Don Heaton, President, Indiana County Surveyors' and County Engineers' Association.

Some Policies of the Indiana State Highway Commission—
Mr. George E. Hershman, Member, Indiana State Highway Commission.

Selection of a United States Highway System with Standard Highway Signs—
Mr. E. W. James, Chief, Division of Design, U. S. Bureau of Public Roads, Washington, D. C.

Evening

Dinner-Smoker in Purdue Memorial Union Building.

Presiding—Prof. Ben H. Petty, Asst. Prof. of Highway Engineering, Purdue University.

Addresses—
Hon. H. G. Leslie, Speaker of the House, Indiana State Legislature.
Hon. R. M. Southworth, Indiana State Senator.
Songs—Movies—Stunts—Smokes.

TUESDAY, JANUARY 19th

Morning

Presiding—Prof. Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

Use of Rock Asphalt and Emulsified Asphalt on County Roads—
Mr. S. B. Mylin, Wabash County Highway Superintendent.

Discussion—
Mr. George Dix, Clark County Highway Superintendent.

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Economical Design of Concrete and Other Hard Surface Pavements—
Mr. Frank T. Sheets, Chief Engineer, Illinois Division of Highways.

Discussion—

Some Pointers on Bituminous Macadam and Surface Treatment Road Work—
Mr. E. B. Lockridge, District Engineer, Indiana State Highway Commission.

Discussion—
Mr. H. C. Offutt, District Engineer, Indiana State Highway Commission.

Afternoon

Presiding—Mr. Don Heaton, President, Indiana County Surveyors' and County Engineers' Association.

The County Surveyor's Responsibilities in the Building of County Roads—
Mr. Homer Teeters, Jay County Surveyor.

Discussion—
Mr. Dave Harker, Clinton County Surveyor.

Greater Safety at Railroad-Highway Crossings (Illustrated)—
Mr. Chas. E. Hill, General Safety Agent, New York Central Lines.

Discussion—

The County Surveyor's Organization for Field and Office Work—
Mr. H. D. Hartman, Wabash County Surveyor.

Discussion—
Mr. Wm. Morthland, Porter County Surveyor.

WEDNESDAY, JANUARY 20th

Morning

Presiding—Mr. W. O. Jones, President, County Highway Superintendents' Association.

Construction of Small Concrete Bridges and Culverts—
Mr. H. A. Blunk, City Engineer, Martinsville; ex-Morgan County Highway Superintendent.

Discussion—
Mr. C. T. McCoy, Howard County Highway Superintendent.

Review of the Work of the Division of Maintenance, Indiana State Highway Commission—
Mr. A. H. Hinkle, Superintendent of Maintenance, Indiana State Highway Commission.

Discussion—

Drainage Features on County Roads—
(a) The Engineer's Viewpoint:
Mr. George R. Harvey, Hendricks County Surveyor.
(b) The Maintenance Viewpoint:
Mr. Wm. Tonkel, Allen County Highway Superintendent.

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Afternoon

Presiding—W. A. Knapp, Professor in Charge, Engineering Extension Department, Purdue University.

Efficient Co-operation Between the County Surveyor and Highway Superintendent—
Mr. Paul U. Lannard, Huntington County Surveyor.

Discussion—
Mr. Byron Platt, Dekalb County Highway Superintendent.

Traffic Obstacles—
Mr. Howard R. Olson, Engineer, Chicago Regional Planning Association.

Discussion—

Improvement of Township Roads—
Mr. Clyde Piper, Fayette County Highway Superintendent.

Discussion—

THURSDAY, JANUARY 21st

Morning

Presiding—Mr. A. H. Hinkle, Superintendent of Maintenance, Indiana State Highway Commission.

An Experimental Road in St. Joseph County—
Mr. A. C. Mangus, St. Joseph County Highway Superintendent.

Discussion—
Mr. P. R. Gillin, St. Joseph County Engineer.

Road Maintenance Methods—
Mr. B. C. Tiney, Maintenance Engineer, Michigan State Highway Department.

Discussion—

Construction of Stone Roads—
Mr. E. D. Nesbitt, Jasper County Surveyor.

Discussion—
Mr. J. R. Deardurff, Newton County Surveyor.

Construction of Gravel Roads—
Mr. C. C. Kain, Dekalb County Surveyor.

Discussion—

Afternoon

Presiding—Prof. Ben H. Petty, Assistant Professor of Highway Engineering, Purdue University.

Maintenance Equipment—
Mr. Harry J. Kirk, State Highway Engineer, Ohio Division of Highways.

Discussion—

Economical Design of Road Structures—
Mr. W. J. Titus, Chief Engineer, Indiana State Highway Commission.

Discussion—

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Concrete Facts (demonstration)—
Prof. R. B. Crepps, Assistant Professor of Testing Materials, Purdue University.

Discussion—
Mr. P. D. Meisenhelder, Testing Engineer, Indiana State Highway Commission.

Evening

Annual Banquet in Purdue Memorial Union Building.

(Program broadcast from Purdue Radio Station W. B. A. A.)

Presiding—Prof. W. K. Hatt, Head, School of Civil Engineering, Purdue University.

Addresses—
President E. C. Elliott, Purdue University.
Mr. John Brown, Chairman, Indiana Tax Commission.
Annual Meetings of Co-operating Associations.

FRIDAY, JANUARY 22nd

(Note—Separate sessions scheduled)

GENERAL PROGRAM FOR CITY OFFICIALS.

Lecture Room No. 101, Civil Engineering Building.

Morning

Presiding—Prof. G. E. Lommel, Associate Professor of Topographical Engineering, Purdue University.

Maintenance of Gravel Streets—
Mr. E. D. Canatsey, Morgan County Surveyor.

Discussion—
Mr. E. B. Vawter, City Engineer, West Lafayette.

The City's Share in Our Traffic Problems—
Mr. W. P. Cottingham, City Engineer, Gary.

Discussion—

Afternoon

Laws Governing Municipal Improvements—
Mr. W. S. Moore, Consulting Engineer, South Bend.

Patching and Resurfacing City Pavements—
Mr. D. B. Davis, City Engineer, Richmond.

Discussion—
Mr. Claude Draper, City Engineer, Lafayette.

Discussion—

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FRIDAY, JANUARY 22nd
COUNTY HIGHWAY SUPERINTENDENTS.

Morning

Ball Room, Memorial Union Building.

Presiding—Mr. W. O. Jones, President, County Highway Superintendents' Association.

Roadside Weed Cutting—
Mr. J. F. Crowe, Porter County.
Mr. Frank Marks, Dubois County.

Stone Road Maintenance—
Mr. W. S. Parks, Jasper County.

Size and Quality of Maintenance Gravel—
Mr. W. H. Jarrett, Tipton County.
Mr. John E. Ferrier, Carroll County.
Mr. M. M. McCloskey, Warren County.

Daily Reports—
Mr. W. F. Eberhart, Huntington County.
Mr. Elmer Blue, Putnam County.
Mr. Matt Foster, Vanderburg County.

Afternoon

Room No. 101, Civil Engineering Building.

Presiding—Mr. Matt Foster, Vice-Pres., County Highway Superintendents' Association.

Heavy Grading Equipment—
Mr. S. N. Johnson, Clinton County.
Mr. K. H. Dimmich, Benton County.

The Value of Local Annual Meetings for County Road Men—
General Discussion.

Taking Township Roads Into the County System—
Mr. W. O. Jones, Wayne County.

FRIDAY, JANUARY 22nd
COUNTY SURVEYORS AND ENGINEERS.

Morning

Reception Room, Memorial Union Building.

Presiding—Mr. Don Heaton, President, County Surveyors' and County Engineers' Association.

Improving Local Gravel for Road Purposes—
Mr. Fred Hubbell, Steuben County.

Discussion—

Surveys and Plans for County Roads—
Mr. Wallace Southard, Marion County Engineer.

Discussion—

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Inspection on County Roads—
Mr. R. W. Meisinger, Vanderburg County.
Mr. Donald Lessig, Kosciusko County.
Mr. H. J. Lemme, Dubois County.

Right-of-Way Widths—
Mr. Harley K. Spears, Lagrange County.
Mr. Don B. Thomas, Hancock County.
Mr. Earl Alexander, LaPorte County.

Afternoon

Room No. 1, Civil Engineering Building.

Presiding—Mr. William Parrett, Vermillion County Surveyor.

Care and Adjustment of Levels and Transits—
Prof. G. E. Lommel, Associate Professor of Topographical Engineering, Purdue University.

Discussion—

Design of Small Truss Highway Bridges—
Prof. E. L. Eriksen, Professor of Structural Engineering, Purdue University.

Discussion—

Sub-Drainage—
Mr. Don Heaton, Benton County.

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SOME POINTERS ON BITUMINOUS MACADAM AND SURFACE TREATMENT ROAD WORK

By Earl B. Lockridge,
District Engineer, Indiana State Highway Commission.

Bituminous macadam, also known as penetration macadam because of its type of construction, is probably done an injustice more frequently than most any other type of pavement through inferior construction, attempts to construct too cheaply, and the salvaging of old gravel and stone surfaces that are not worthy of the consideration given them.

The quantity and quality of material that combines to make this pavement is of the utmost importance, yet no less important is the skill and judgment of workmen who assemble, rake, spread, penetrate, roll and mould these ingredients into the final compact surface. Weather conditions are a factor and must always be taken into account, low temperatures and dampness being especially objectionable. Unlike some types of pavement wherein costly mechanical appliances have been provided, which, if operated by honest hands, will do uniformly good work, the degree of refinement and perfection of a bituminous macadam job depends to a large extent upon the skill of workmen and the knowledge and alertness of the inspector in charge.

It is well to surface-treat a bituminous macadam pavement the first and probably second year after construction, and thereafter as surface conditions require. Original construction and surface treatment may be of either tar or asphalt. The lighter tar being more pliable, has been found to be quite practical for the first treatment after construction. It may be gone over with the ordinary drag such as is used in stone and gravel road maintenance. The drag carries surplus material (tar and stone chips) to the low places, also helping to eliminate the mechanical defects if any exist. The asphalt treatment will ordinarily wear longer and not need to be repeated so often. Those roads of which I have had personal observation, have had treatments ranging from a third of a gallon of bituminous material per square yard of surface, when first taken over by the state in bad condition, to as low as one sixth of a gallon per square yard of surface when found in good condition, treatments coming about every other year.

Before applying bituminous material, the surface to be treated must be thoroughly cleaned and dry. Traffic should be

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kept off, both for its own protection and the good of the work, until after covering material has been added. If possible the road should be closed for one or two days, though in actual practice, I suspect there are more cases where traffic is merely warned of fresh bituminous materials than there are where the road being treated is really closed. The bituminous material should be uniformly applied at proper temperature from an approved pressure distributor.

It is essential and imperative that covering material be applied without delay after a surface has been treated, said covering to consist of stone, slag or gravel, thoroughly clean and graded closely between one-quarter and three-quarter inch in size. An excess of the larger size is preferable when treating an open, comparatively rough surface, while the smaller size is desirable when you have a surface that is well closed and smooth. The quantity of covering material to be used per square yard of surface depends upon the condition of the surface, the grade of tar or asphalt being applied, and the amount of same that is applied per square yard of surface. For estimate purposes, where tar is used, it might be said that fifty-four pounds of stone to the gallon or one cubic yard to forty-six gallons and where asphalt is used eighty-eight pounds of stone to the gallon or one cubic yard to twenty-eight gallons of the bituminous material is about right. The same gallonage would prevail per cubic yard for slag or gravel. The covering material should always be spread direct from dump trucks as they will spread it more uniformly and cheaper than can possibly be done by hand from piles or conveyance not equipped with dump. A bituminous macadam pavement properly constructed will improve under traffic and maintenance, riding smoother year after year.

Lincoln Highway

It has been my lot to have charge of the Lincoln Highway through Porter and LaPorte Counties where the State Highway Commission through its Maintenance Department has reconstructed the entire section of twenty-one miles between the cities of Valparaiso and LaPorte. Within this distance there were many vexing, if not contemptible things to handle, not the least of which was the matter of securing sufficient right-of-way on which to construct and operate a creditable pavement. There were drainage pipes and small concrete culverts to extend, new alignments requiring fills of half or entire width of roadbed, narrow grades to be widened, and worst of all a satisfactory base course to be prepared on which to place the bituminous top. Parts of the original road

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had been well constructed as a waterbound macadam pavement (though with excess crown) to the width of ten and twelve feet and later surface treated, then parts were allowed to lapse into an ordinary stone road through failure to follow up with subsequent treatments. Other parts of this road consisted of a conglomeration of stone, slag, gravel, and cinders varying in width, depth, and quality of material until it was difficult to know just what additional new material should be added in preparing suitable base without being extravagant. The outer three feet on either side of an eighteen foot strip had to be built up throughout and a light waterbound course was necessary over the entire top, in most cases, to reduce the crown of the old surface when not required to give additional strength of base. At a few points it was found necessary to alter grade because of abrupt changes, but in the main every bit of the old road was salvaged and stands today as a part of the new construction, the taxpayer still realizing from the original investment in roadbed, stone, and drainage structures. This is the feature that should appeal to the taxpayer in this type of construction—nothing is wasted or destroyed that already exists.

Maintenance

Having misjudged strength of base or through other causes having secured faulty pavement, the matter of maintenance or repair becomes a more difficult problem. If the pavement breaks near the edges it indicates a weak base, poorly compacted fill in widening the roadbed, or lack of rolling or perhaps insufficient drainage. There may be a spot that shows signs of raveling or rutting due to insufficient bituminous material or failure to penetrate because of dirty surface closed too tightly or saturated with water. Whatever the cause may be it is well that those who have in charge the matter of making repairs should at first attempt to diagnose the case and then proceed to remedy both defect and cause in an intelligent manner, using one of the several grades of tar or asphalt best adapted to the character of repairs to be made.

Bituminous macadam surfaces can always be patched without seriously interfering with traffic. Patches are made of premixed cold or heated materials, or by penetration method if of sufficient size to warrant same and may be either hand tamped or rolled into place. More frequently the cold mix materials are used (tar T.C.M. or emulsified asphalt) and the patches being small and far apart, are compacted with hand tamp. The refinement to be attained in patching or eliminating construction defects, is entirely within the hands of those

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performing the task. A skilled man with mechanical eye will feather-edge his work until you cannot tell where the patch is except by color and not at all after the next surface treatment has been applied.

The size of aggregate to be used should vary with the depth of patch or repairs that are being made. A deep patch might be made with all fine aggregate, but it would be more practical if the coarser sizes of stone were used, and with the thin layer to be feather-edged it is obvious that the smaller aggregate will have to be used. There is a small amount of settlement due to the mixed material compacting under tamp, and under later traffic, varying with the depth. That feature is readily mastered by the observing workman who can make proper allowance.

Where it becomes necessary to make repairs because of raveling or desire to eliminate a low spot due to faulty construction, the hole or surface is thoroughly swept and cleaned of all loose or foreign matter and painted lightly with the bituminous material of which the patch is being made. This insures bonding and helps to seal against moisture getting under the patch. Likewise the top should be sealed and made more dense by brushing a thin coat of the bituminous material over it and applying some fine stone or coarse sand. It is very necessary to have a dry surface and dry aggregate when using any of the bituminous repair materials except emulsified asphalt. This material may be used on a damp surface with damp aggregate, the only difference being that you mix less water with the emulsified asphalt under those conditions.

Surface Treatment

Surface treatment road work consists of two distinct types, that following the construction of a bituminous macadam pavement and that wherein the first bituminous material used consists of a treatment direct to the surface of a waterbound macadam, stone or gravel road. A well constructed waterbound macadam road that is not burdened with excessive traffic can be treated, made dustless, less costly in maintenance and frequently pass as a bituminous macadam job at a very low cost. If, when constructing the waterbound macadam road, it is known that a bituminous treatment is to be given, it is well to reduce the quantity of the screenings so as to leave the top stone exposed, making it possible for the bituminous material to adhere to more of the surface of this coarse aggregate. A waterbound surface must be thoroughly swept and cleaned of all foreign matter before treatment. The sur-

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face must be dry and the temperature of the atmosphere above 45 degrees Fahrenheit. The temperature of the bituminous material to be as specified for the grade used and to be uniformly applied from an approved type of pressure distributor. Ordinarily on this type of surface treatment work, the gallonage per square yard of surface is much greater than used on bituminous macadam maintenance, necessitating two or more applications. It should never be applied at such rate as will permit of bituminous material running off the edges of the metal and wasting.

The same principles involved in treating bituminous macadam and waterbound macadam also prevail in the treatment of stone and gravel surfaces. Under proper conditions, the first application of say three-tenths of a gallon per square yard will penetrate until it entirely disappears from the surface. After this treatment has been given sufficient time (perhaps twenty-four hours) in which to penetrate and get set, additional treatment or treatments follow until the required amount of bituminous material has been applied. Then the surface is covered with fine stone, slag, or gravel, the quantity depending upon condition of surface and amount of excess bituminous material that remains to be absorbed. It may be necessary to give a very light application of covering material after each application of bituminous material, to prevent flowing to the edges in case of smooth surface and excess crown, also to prevent picking up on distributor wheels when making the next application. After the last application and all covering material is in place, the surface should be dragged repeatedly until every chip or pebble is thoroughly coated and the surface becomes tacky. Traffic should be kept from the surface throughout the process of treatment and for about two days after dragging operations have ceased, during which time a curing effect takes place leaving a dry dustless surface that will stand up under quite heavy traffic. This is very cheap and practical maintenance when properly carried out under favorable conditions, though I fear it is too often tried as an experiment under adverse conditions, thereby resulting in the abominable pot holes and abrupt breaks in the surface such as we frequently find on heavy traveled streets through the smaller towns where an attempt has been made to eliminate the dust, regardless of the kind of surface to be treated, the grade of material to be used or the correct manner of applying.

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USE OF ROCK ASPHALT AND EMULSIFIED ASPHALT ON COUNTY ROADS

By S. B. Mylin,
Wabash County Highway Superintendent.

Wabash County believes that it can keep its traffic out of the mud without the vast expenditure of money required to build complete new hard surface highways. Just because an old gravel or stone road is rough and unpleasant to travel, many citizens and even many engineers are disposed to condemn it entirely and demand a new pavement. Stop and figure the average cost of new pavement, and you will be staggered by the sum required to reconstruct your roads. You will realize, just as we did, that some other solution of your road problems must be found.

Six years ago we adopted the practice of resurfacing old gravel and macadam highways. Naturally, resurfacing was first attempted on heavy traffic roads which were requiring excessive maintenance. Test holes showed plenty of old metal to carry the traffic. In fact it was rare to find even small areas where the roadways had broken through to the clay subgrade. The only complaint was that the roads were rough and dusty.

Although each resurfacing project presented a different problem, in general, our procedure was to shape the old roadway by scarifying and rolling. We then laid, when needed, a thin course of crushed limestone, rolled it until it was thoroughly keyed and surfaced the entire roadway with rock or emulsified asphalt. The first of these resurface jobs came in 1919 in the town of Urbana. This resurfacing was done with critical conditions against us. The taxpayers and the newspapers were opposed to this project. This street, built of rock asphalt, is carrying its sixth year of heavy traffic without one cent of maintenance. By 1922 the taxpayers and newspapers were on our side.

The taxpayers of North Manchester demanded that the Hills and Lakes road from the college north seven-tenths of a mile be resurfaced with rock asphalt. This road which is very heavily traveled is on its fourth year without one cent of maintenance.

In 1923 we had a road leading out of North Manchester on the Hills and Lakes route that had been built of asphaltic concrete. This road had been in service only six years and had to be resurfaced. We resurfaced it with emulsified asphalt and it is in fine condition with no expense for maintenance.

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The next road on the program in 1923 was the Linlawn road leading from the corporation line of South Wabash. This was an old road built of stone and gravel. We did not add any new metal but just reshaped and rolled the old metal. Then we covered this with emulsified asphalt. Under very heavy travel this road has remained in perfect condition without any maintenance.

In 1924 we built one and one-half miles on the Hills and Lakes road adjoining that built in 1922, making a total length of two and two-tenths miles. This road was built of rock asphalt.

In 1924 we built two approaches to Wabash, the Walnut Tree road and Falls Avenue road. These two roads were built of emulsified asphalt.

In 1925 we built the following roads:

TABLE 1.

Name	Berms	Width Ft.	Length Ft.	Surface Sq. Yds.	Cost Per Sq. Yd.
Rich Valley	Stone	16	2,320	4,120	$1.29
Linlawn	Stone	16	3,350	4,840	1.34
Laketon	Stone	18	1,600	3,200	1.42
East North Manchester	Stone	18	3,320	6,640	1.33
Somerset		18 and 24	2,400	5,067	1.53
Chippewa	Gravel	18	3,200	6,400	1.52

The latest resurfacing project in Wabash County is the Chippewa road leading northwest from the city of Wabash and subject to very heavy traffic. The old gravel road was a source of constant complaint and heavy maintenance. We first scarified and reshaped by rolling. Where there was any evidence of weakness in the old base, it was strengthened by adding new limestone and thoroughly compacted. We then laid a course of emulsified asphalt concrete, one and one-half inches thick after compression and, over this, a wearing surface of rock asphalt approximately three-fourths of an inch thick compacted.

The county has used a great deal of rock asphalt and emulsified asphaltic concrete with good results. The idea of combining the two materials on this job was an idea of my own to develop a type which would be both serviceable and economical. The emulsified asphaltic concrete was used as a binder course and could be laid much thinner than water-bound macadam. The rock asphalt was used as a waterproof wearing surface. We felt that with the emulsified asphalt binder course we could materially increase the strength of the

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road with very little added cost. This road at the present time looks fine and we are receiving many compliments on it.

The taxpayers of Wabash County are very much in favor of this resurface work. We increased our road maintenance levy, for 1926, six cents and had no opposition to the increase. Our heaviest farmer taxpayer said that we should have made it higher as the people want more resurfaced roads built by the highway maintenance department. There is not one faction in Wabash County today that is fighting us on this program. They are all for us—they want the roads.

USE OF ROCK ASPHALT ON COUNTY ROADS

By George Dix,
Clark County Highway Superintendent.

The Plant Road between Jeffersonville and Charlestown was built about 12 or 14 years ago. This is a macadam road and has been difficult to maintain, requiring reworking two or three times each year. It carries a very heavy truck and auto traffic from the northern section of the county, and is through a very low, swampy section.

The old road was built 16 feet wide with an average depth of about eight inches. We first scarified the entire width of the road and graded it to proper crown, (about 2¼ inches) and also widened it to at least 17 feet of stone with a 4 foot earth shoulder on either side.

We added 4 inches of new limestone from 3½ inches down to 2½ inches in size, rolling thoroughly with a 10 ton roller. Screenings were applied for filling voids, rolled thoroughly, and filled again with screenings, using hand brooms for working it in. We watered the road until no more water would penetrate it, and kept rolling until the mixture of water and screenings would push up in a wave in front of the roller. The road was allowed to dry thoroughly and then swept with hand brooms in order to give at last a half inch key for the rock asphalt to prevent crawling.

Before laying the rock asphalt, we swept and thoroughly cleaned the wearing surface. Where the base had been damaged or disturbed we repaired it before spreading the asphalt. The asphalt was laid on a dry base with the temperature at 50 degrees F. or above. The rock asphalt was dumped in piles

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in the center of the road just ahead of our work. Excess asphalt was loaded in trucks and carried ahead.

After we spread the asphalt with shovels, all lumps were broken up and the material was shaped with heavy hand rakes. We continued the raking until the surface was free from honey-combed places, true to grade and of the proper thickness.

We used side forms about 3½ inches wide, and intermediate forms ⅜ inches in width, 1¼ inches thick spaced about five feet apart and laid parallel with the center line of the road to gauge the proper thickness. The height of these forms determined the depth of the course after it was completed. Before removing the side forms, the edge was tamped vertically with a hand tamp, and after the sides had been carefully taken away the edge was tamped at a 45 degree angle before we backed it up with earth.

After the material was raked, it was permitted to lie in the sun and heat until it took on a black oily appearance, when it was rolled with a 10 ton roller. The surface was rolled once each day for four days in succession. After the first rolling, we used extra material to bring up the low places and removed material from those that were too high, and the road was again rolled until all marks had disappeared. The pavement was not opened for traffic until after the final rolling.

The finished surface at no place varies more than ¼ inch from a cross-section template, nor from a 10 foot straight edge laid parallel to the center line of the pavement.

SALVAGING OLD PAVEMENTS BY USE OF BITUMINOUS MATERIALS

By H. C. Offutt,
District Engineer, Indiana State Highway Commission.

In doing work of this nature, we have found we get good results by confining ourselves to the use of a bituminous concrete made with a stone aggregate and a tar binder, and mixing both at normal temperature. We have used other variations and have obtained good results, but in this discussion we will touch only on this one kind of mix.

The work, while all done at the same time and by the same organization, is actually divided into two processes. All depressions which require filling, and which are not over one-

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half inch in depth, are taken care of by a process which we call "paint patching." In this class of work, the depressions after they are marked out, are painted with a hot tar and covered with stone screenings or pea gravel.

The depressions which are over one-half inch in depth, we fill with the bituminous concrete and cover same with a seal coat. The depressions when they are not over two inches in depth are painted with hot tar, as in the first case, before the bituminous concrete is applied.

Estimate of Work

The conclusions we will give you under this subject are only rough approximations. They are stated for the purpose of giving the superintendent a guide in ordering his materials and are not to be used as a specification for doing the work.

From studies made of our work during the past season, we have arrived at the following:

(a) The average patch will range in size from three square yards to five square yards. Judgment in the field will have to decide which figure will best suit your piece of work.

(b) One square yard of patch requires about:
0.5 gal. tar for painting the depressions.
0.25 gal. tar for mixing the bituminous concrete.
0.25 gal. tar for seal coat.
0.33 cubic foot of stone aggregate.
0.33 cubic foot of screenings.

We believe that a road surface which is considered rough will have about two hundred patches per mile. One which is very bad will average as high as seven hundred per mile. Figuring an estimate for repairing one mile of surface having about two hundred patches per mile, and figuring three square yards as average size of patch, we would have the following:

Patches per mile	200	
Square yards of patch	600	
Materials:		
Tar for painting patch		300 gal.
Tar for bituminous concrete		150 gal.
Tar for seal coat		150 gal.
Total tar		600 gal.
Stone aggregate for bituminous concrete	7½	cu. yds.
Stone screenings	7½	cu. yds.
Total stone	15	cu. yds.

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Cost of materials:

600 gal. tar	$100	00
15 cu. yds. aggregate or screenings	45	00
Miscellaneous hauling, crayons, etc., 10%	15	00
	$160	00
Labor, 90%	145	00
Total	$305	00

These figures cover the average amounts of material used for a ten-mile project in Warrick County, the surface conditions being about the same as stipulated above.

Organization

On a fair sized job it is best to so organize your gang that one man will be kept busy at one or two operations continuously. He can soon be taught to do these few operations quickly and easily without being watched. A gang organized on this basis should consist of the following:

(a) The foreman of the gang has many duties. First of all he exercises a watchful attitude over the whole gang and keeps the work going smoothly. He should watch the work of the marker and finisher very closely, as their work must be done right. He checks over the finished work carefully and corrects any bumps which have been left. He usually applies the screenings in making the paint patches and assists the tar man in applying tar when necessary, and moves the equipment along the road as progress is made. A good way for the foreman to keep a check on results of his work is to look back over the work occasionally and notice whether cars going at a good rate of speed do any bouncing. Usually if a bump has been missed or a patch made too high, it can be detected in this way, or if he has a car available he can try it out himself, checking the uneven spots as he drives over the finished work.

(b) Two men to mix the tar and stone (making the bituminous concrete) and deliver it to the patching gang.

(c) One man to measure and mark out the patches. When he gets ahead with the marking, he should drop back and assist the wheelbarrow man by loading the empty wheelbarrow for him.

(d) One man to sweep the surface where the patch is to be made. This man has some spare time which is taken up by helping the wheelbarrow man, usually by loading his empty wheelbarrow.

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(e) One man to tend the tar kettle, handle and pour hot tar on the depressions.

(f) One man to wheel and shovel the bituminous concrete on to the patch.

(g) One man to spread the bituminous concrete and finish off the patch.

Equipment

The equipment necessary for a gang of this size should consist of the following:

One truck, two-ton capacity.
One truck, one-ton capacity.
One trailer, two-ton capacity.
One concrete mixer, seven cubic feet capacity.
Three wheelbarrows.
One tar heater, 200-gallon capacity.
One wire push broom.
One fibre push broom.
One stable broom.
One 14 foot straight-edge.
One 16 foot straight-edge.
Two tar pouring cans, two-gallon capacity.
Four pails, ten-quart capacity.
100 feet of common chalk line.
One box of boilermakers crayon.
Two finishing shovels.
Various square point and round point shovels and scoops.

The two-ton truck is used to pull the trailer, and tar kettle and also to hold the screenings.

The one-ton truck is used to haul the bituminous concrete from the mixing plant to the patching gang and also to haul the men to and from work.

The concrete mixer must be a tilting drum type to give satisfactory results.

The straight-edges are 2 inches by 6 inches, one 14 feet long and one 16 feet long. They are best made from cypress, as they should be as light as possible. They are made two inches thick to prevent warping. The 14 foot straight edge is for the finisher and the 16 foot size is for the marker.

The tar pouring cans are made from galvanized sprinkling cans with the spout cut off about 1½ inches from the body of the can, and the remaining part of the spout squeezed almost together, leaving an opening of about ¼ inch by 5 inches. This kind of an opening tends to spread the tar very uniformly and saves time.

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The finishing shovel is a long handled shovel, as light as possible, having a square point 12 inches wide. A wider point is hard to handle and one more narrow slows down the speed of the finishing. This can be made by putting a long shovel handle in an old gravel scoop. Usually an old scoop will be worn thin, which makes a light, serviceable tool. The gravel scoop point can be heated and the point flattened out so that it will be level all along the bottom of the point.

The crayons used will run about thirty-six to the mile.

Materials

The tars used are T. P. 2, T. M. and T. C. M. The T. P. 2 is used to paint the depressions to hold the screenings or bituminous concrete in place and also to make the seal coat. If there are a large number of square yards to coat, then T. M. should be used. The T. C. M. is used to mix with the aggregate to make the bituminous concrete.

The aggregate is usually of stone, although in the gravel country pea gravel can be used instead of screenings. The sizes of aggregate used are as follows:

No. 6 (screenings)	½ inch to ¼ inch
No. 45	¾ inch to ¼ inch
No. 3b	1 inch to ¼ inch
No. 34	1½ inch to ¼ inch

We used as large size aggregate as possible in the bituminous concrete which was to be applied in the depression. To do this, we made three different sizes of bituminous concrete. One size was made out of the No. 45 stone, one size out of the No. 3b stone, and one size out of the No. 34 stone. In a depression having a depth of ½ inch to ¾ inch we applied the bituminous concrete or mix made of the No. 45 stone, In one having a depth of ¾ inch to 1¼ inches we applied a mix made of the No. 3b stone. In one having a depth of 1¼ inches to 2 inches we applied a mix made of the No. 34 stone.

In almost any depression a slightly larger sized stone should be used than the depth indicates. It is always advisable to use as near the proper sized aggregate to bring the surface up to normal as can be used. This we think would apply to any patch with a depth up to four or five inches, using for a four-inch depression a three or four-inch stone if available.

Operation

The mixing plant should be located near the road and moved when necessary so as to never be more than two and

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one-half miles from the patching gang. At this plant should be kept the aggregates, the tars and the equipment for mixing. The equipment will include the light truck, the mixer, two ten-quart pails, shovels and scoops.

Careful attention should be given to the arrangement and layout of the plant so that all lost motion is eliminated. One good way is to place each size of aggregate in a pile, arranging the piles in a row, so that the mixer can be moved along the row and the aggregate loaded direct from the pile into the loading hopper. The correct amount of aggregate is measured and placed in the hopper and leveled. A line is then painted around the inside, at the height of the leveled aggregate, which shows the loader how much stone to put into the hopper for each batch. The barrels of tar T. C. M. should be handy to the mixer, but not in the way. They should be elevated above the ground high enough to place a pail under the bung. A standard molasses gate screwed into the bung saves time in handling the tar and also eliminates considerable waste.

The mixing is done by two men. One man loads the receiving hopper and brings the tar for the next batch. The other man dumps the mix onto a dumping platform, from which he then loads it into the light truck, ready to be hauled to the patching gang.

The batch must be allowed to thoroughly mix until each particle of the aggregate is completely coated with tar. The stone must be thoroughly dry and free from dust and dirt. Tar and damp stone will not mix. Bituminous concrete made with damp stone and put on the surface will disintegrate and ravel under traffic. A two or three days' supply of stone is kept covered during the night and during rainy weather. In this way enough stone can be kept dry to keep the work going until the wet stone dries out. When a gang is off for a couple of days it disrupts the organization and it will take about half a day to get them lined out again when they do get started.

For one cubic yard of aggregate, we use from fourteen to sixteen gallons of tar T. C. M., this amount being regulated by the size and cleanness of the stone. The temperature also has some bearing upon the amount used.

These two men can mix and deliver to the patching gang about one cubic yard of mix per hour. One batch will make about five cubic feet of mix. The average time of mixing a batch is about four minutes, the balance of the hour being taken up in loading and delivering the mix to the patching gang. The average daily consumption of mix for a gang of this size will run from seven to eight cubic yards, so by the

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time the mixers produce this much mix, clean up and get ready for the next day's run, their time is pretty well taken up.

Patching Operation

On the way to work in the morning, the patching gang stops at the mixing plant and loads up with materials. The truck is filled with two cubic yards of screenings, on top of which two or three barrels of tar T. P. 2 are placed. The trailer is filled with various amounts of the three sizes of bituminous concrete, depending upon the character of the surface to be patched that day.

Arrangements should be made by the foreman that one of the gang, the first thing in the morning, goes to the tar kettle and starts a fire, so that the tar is ready for pouring when the gang arrives on the job.

Outlining the Depression.—This is done with a straight edge or line. It is a rather tedious task and should be done by some one who is a reliable workman. The depression is outlined with crayon, marking where the straight edge and surface begin to separate. The straight edge is laid parallel with the center of the pavement about one foot from one edge. Marks are drawn on the pavement showing the outside limits of the depression, the straight edge is then moved over about 18 inches or 2 feet and the marking continued until the other side is reached or the patch runs out. The marker should also write the depth of the depression just outside the outline so the men applying the bituminous concrete will know what size mix to use.

The marker outlines all depressions of ¼ inch depth that are over three or four feet in length. Depressions of this depth, but over four feet long will not cause a car to bounce. Occasionally the marker will find a depression that the 16-foot straight edge fails to cover. The foreman then assists him with a line, the line being held to the surface on each side of the depression, which is then outlined the same as when using a straight edge. On a place of this kind, the foreman must use his good judgment as the depression might be entirely too long to repair. If the depression is not over 1¼ inches deep, its length over 18 feet, and its approaches to the normal surface are gradual, it would not need filling.

Cleaning the Surface.—Following the marker, the sweeper thoroughly cleans the surface, using a wire push broom and a stable broom. The wire push broom is used to scratch loose any foreign matter which may be stuck to the surface and the stable broom is used to sweep the dust off.

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Painting the Depression.—As soon as the depression is thoroughly cleaned, the tar pourer applies a coat of hot tar T. P. 2 to its surface, except when the depth of the depression is over two inches. Where the depression is shallow (¼ inch or under) the application is made slightly heavier, as it is to be a part of the paint patch. The tar pourer should use two two-gallon tar pouring cans instead of one four-gallon can, as the two-gallon cans are much easier to handle. After the tar is applied to the depression, he spreads it with a fibre push broom. We first used a squeege but found that the fibre broom made a more uniform spread, the squeege having a tendency to ridge the tar at its ends, which makes a ridge in the paint patch. This trouble, however, is more noticeable in repairing a rigid pavement than it is on a bituminous macadam.

Applying the Screenings, (Paint Patch).—On the outside edge of the depression where the depth is under ¼ inch, or over the whole depression if it does not exceed ½ inch, the dry No. 6 screenings are applied. Judgment must be used in applying the tar and screenings in making these paint patches or feather edging the bituminous concrete patches. More tar and screenings, making a thicker mat, are applied at the deeper spots so that when finished, the patch on its surface will be smooth and level with the surrounding surface. The foreman himself should apply these screenings because it is particular work.

Too many times we find the men applying too thick a coat of screenings. While this extra thickness of screenings is not harmful to the patch as the tar will only absorb so much, it is a waste of material. The dry screenings and hot tar are used for this purpose in preference to a bituminous mix, using this size aggregate, because it is more convenient to handle and finishes off much better than the bituminous mix on these thin patches.

Applying the Bituminous Concrete.—After the feather edge paint patch has been made on the outer edges of the depression, the bituminous concrete is applied. The wheelbarrow man brings the bituminous concrete to the depression in a wheelbarrow. Two wheelbarrows should be used, as the marker and sweeper will have time to load the empty wheelbarrow while the other is being emptied.

The wheelbarrow man must place the bituminous concrete where the finisher wants it, namely: close to the feather edging or on the edge of the bituminous concrete previously placed. It is then worked over into place toward the center by the finisher, using the finishing shovel, until a uniform surface is obtained.

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The bituminous concrete in any one depression is usually of one size mix, but if the depth of the depression becomes deeper than 1¼ inches at any place, a mix of 1½ inch aggregate should be used in these spots. In a case like this, the outer edges of the depression would be taken care of with the feather edge paint patch, the next portion from ¼ inch to 1¼ inches in depth, with the No. 3b mix, and the portion over 1¼ inches deep, with the No. 34 mix. It is not best to use the No. 34 mix to take care of the whole depression as it will contain too many large stones to give a satisfactory and even surface.

Finishing the Patch.—There are several things about finishing the patch and obtaining a smooth surface which should be mentioned. The foreman and finisher should insist that the bituminous concrete be not dumped into the center of the depression in a pile. See that it is applied by the shovelfull just where the finisher wants it. This allows him to shove it into place with his finishing shovel by pushing it off of the portion already placed, to the surface of the depression. This tends to spread the bituminous concrete more uniformly and eliminates any high or low places after the patch has compacted.

The finisher should always keep his finishing shovel in good shape, so that it will do good work. Often he will find it necessary to remove the gummy substance which collects on the point of his shovel. This can be done very easily by burning it off in the fire-box of the tar kettle. In doing this he should be careful and not ruin his shovel by getting it too hot.

When spreading the bituminous concrete in cool weather, the finisher will find it pays to heat his shovel every few minutes in order to get a good smooth finish to his patch. Usually the sun is hot and glaring when this work is being done. The finisher can relieve his eyes and also judge much better the smoothness of his patch if he will work with the sun to his back as much as possible. Looking down on the patch from this direction does not cause a glare and the uneven places are much more easily detected.

When the weather is very hot and the bituminous concrete has a tendency to be picked up by traffic, a small amount of clean stone (¾ inch to ¼ inch) hand scattered thinly over the fresh bituminous concrete will relieve the trouble. When the depth of the patch is under 1½ inches we do not tamp the bituminous concrete but allow the traffic to do the compacting.

Until the finisher is thoroughly acquainted with his work and his eye trained to detect the slightest irregularity, he

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should always test his patch with a straight edge before leaving it. The foreman should not trust too much to the finisher's eye, but should satisfy himself completely that the patch is satisfactory.

Seal Coat.—If the work is smoothing a bituminous macadam surface prior to a surface treatment, the seal coat is not necessary. The surface treatment itself will supply the wearing coat and seal the open places.

When the work has been smoothing a rigid pavement surface, the bituminous concrete portion of the patches must have all the open places closed or sealed. It is best not to do this until the traffic has thoroughly compacted the patch and any unevenness which may have developed has been corrected.

This seal coat is applied by painting the bituminous concrete with a hot tar T. M., about 0.25 gallon to the square yard, and then coating the surface with our No. 6 screenings at the rate of about 0.25 cubic foot per square yard. If the job is small, or tar T. M. is not available, the tar T. P. 2 will do.

Filling Deep Depressions.—At times we are called upon to fill a depression 6 inches or deeper. The depression should be filled with a stone aggregate up to within two inches of the normal surface. The size of this aggregate should be our No. 1 (4 inches-2½ inches). After this stone has been carefully and uniformly spread and is smooth and level, hot tar T. P. 6 or T. P. 2 is applied at the rate of one and three-quarter gallons per square yard. Immediately after this tar application, a covering material of No. 34 stone should be evenly spread over the surface at the rate of one cubic yard to 160 square yards of surface.

Upon this bottom course is then applied a two-inch course of bituminous concrete made of No. 34 stone. After this has been thoroughly compacted, it should be given a seal coat.

If the job is small, it will not require as large a gang as we have outlined. Often not more than three men will be required. In case the force is reduced, it is better to have the men first mix the bituminous concrete then take it down to the job and make the patches. The superintendent should study the situation, outline the work and assign the various duties as will best suit the reduced force.

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CONSTRUCTION OF SMALL BRIDGES AND CULVERTS BY THE COUNTY MAINTENANCE DEPARTMENT

By H. A. Blunk,
City Engineer, Martinsville, Ex-Morgan County Highway Superintendent.

The statute provides that the county highway superintendent may expend not to exceed $50.00 in the building or repair of any bridge, without consulting the Board of County Commissioners. It also provides that with the consent of said Board, he may expend any sum, not to exceed $100.00, in the building or repairing of any bridge in his road system. All repair and new structures, estimated to cost more than $100.00, shall be taken care of in the regular way, that is, plans and specifications must first be prepared by the county engineer or some competent engineer appointed by said Board of Commissioners, and filed in the office of the county auditor. Notice shall be published in the newspapers of the county for a certain number of times setting out the nature of the work to be done and naming the day and hour when the said board will receive sealed bids from prospective contractors. The contract must be awarded to the lowest and best bidder, in the discretion of said board. They also have the right to reject any and all bids.

In Morgan County we have the greatest respect for the law, and also for the real, honest-to-goodness contractor. The real contractor fills a very important place in this twentieth century civilization. He takes practically all the risk from unforseen conditions, such as floods, labor disturbances and a large number of other things. My hat is always off to such a man, because I know of some of the things with which he has to contend.

Then, you might very properly ask, why I appear here to advocate a different course, and one that appears to be irregular, to say the least.

I answer, that in general, I am not advocating such a course, but desire to enumerate some of the reasons for its adoption in Morgan County, and some of the many advantages accruing to the tax-payer in this particular locality. You are to be the judges of whether such a course will be beneficial or otherwise in your own counties.

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Some Morgan County History

In order to get these reasons properly before you, it will be necessary for me to review some of our county's history in this particular line of bridge building, and you will please pardon my reference to my own connection therewith as I desire to speak as much as possible from personal knowledge rather than from hearsay evidence.

Several years ago I served in the capacity of county surveyor and engineer for a little over seven years, during a period of ten years. This was mostly before the County Highway Superintendent law was enacted. Our small bridges, as well as the large ones, were built by the contract method, and most, if not all of them, with very satisfactory results.

This satisfaction, on the part of tax-payers, I would not have you believe was due solely to the fact that I was the county engineer most of this time, but as much or even more to the other fact that we then had in our county contractors who were experienced and equipped to do this kind of work, and who took some personal pride in the same, knowing that their own reputation depended upon the kind of product which they put out.

Beginning with the years 1917 and 1918, it became very difficult to interest the former contractors in these small projects in Morgan County. I think this lack of interest on the part of contractors was due largely to the engineer's estimates, which did not keep pace with the rising price of both labor and materials during the war period and immediately following the war. This, together with the curtailment of public buildings, caused many former contractors to drift into other lines of adventure or into bankruptcy. Some entered the larger field of state highway work, as our State Highway Commission was created about this time.

Upon the resignation of the county highway superintendent in January, 1924, I was elected for the "bob-tail" term of something less than two years. The county commissioners immediately determined to put all bridge and culvert construction, as well as repair work, under my supervision as county highway superintendent.

Nothing was said to me about the legality of such a course and as I had not been connected with county affairs for several years, and also knew that former superintendents had been doing some work along this line, I very naturally inferred that the law had been amended so as to make such a course perfectly regular.

However, early in the summer of 1924 the State Board of Accounts sent our auditor a number of copies of a pamphlet

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called "County Opinions and Citations." When I received my copy of this little book I immediately discovered that no such change in the law as I had inferred had been made. I at once informed the board of commissioners that we would have to discontinue such a course, or in some way get the approval of the State Board of Accounts, in order to continue it.

At the very first opportunity we took the matter up with the Board of Accounts, and were assured that while they had no power to make or change the law, there would be no objection from them so long as the tax-payer's interests were properly safeguarded.

We then went on with our program throughout the summer and early fall of 1924, building more than twenty small bridges and culverts in various parts of the county, thinking that everything was satisfactory. Late in October of that year, field examiners of the State Board of Accounts appeared on the scene, and I as county highway superintendent was called upon to answer a great many questions in regard to the work which we had been doing in this line. Some tax-payers had complained to the said board about our bridge building program but the names of the complainants were not revealed by the examiners, and none of them have had the inclination to make themselves known as yet.

I was glad to tell the whole story to the examiners and invited them to go out with me and inspect some of the work which we had been doing. They very readily accepted the invitation and after examining two or three jobs which were comparatively close to the county seat, expressed themselves as being well satisfied with the workmanship shown and the relatively low cost.

After the close of the year 1924, I had hoped to be relieved of this line of work and that the commissioners would go back to the contract system so that in case anything was wrong the State Board of Accounts might question someone other than myself. But after the board of commissioners was reorganized in 1925 and the incoming member had had the opportunity to examine some of the work done in 1924 and to learn the cost, he joined heartily with the two old members of the board and the auditor in insisting that we again build by the labor and material plan. The plan was followed throughout the year 1925, with one exception. One job of about a 50-foot span was let by conract. This was a steel superstructure, with concrete floor.

We did not start our work in 1925, however, until we had again consulted the State Board of Accounts, and were again assured that so long as better results were obtained by

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this plan, than by the contract system, no objections would be made.

I will now call attention to a few of the jobs built in both the years 1924 and 1925, with the approximate yardage and cost of same.

Bridge Building Force

Our bridge force consisted of from 6 to 7 men; a foreman, an assistant foreman and 4 or 5 laborers. Neither foreman nor assistant foreman wore white collars on the job and both worked at the actual manual labor, in addition to the mental labor necessary to carry out the plans, just as industriously as any of the other laborers. The foreman was paid 75c per hour, the assistant foreman 65c per hour, and the laborers 40c per hour. When one job was practically completed the foreman would generally keep one or two men with him to do the finishing, trowelling, etc., while the assistant would take the rest of the men and start work on the next job. Both the foreman and the assistant foreman were not only very efficient in mixing and handling concrete but were what I consider expert form builders. I consider proper form building in bridges of supreme importance. I believe more ugly, ill-shaped, unsightly bridges are the result of poor form building than any other one cause. We used this same force of men in all our work throughout the county. Occasionally, however, it was necessary to put on local men but only for the most unskilled part of the work.

Some of the Advantages of the Plan to the Tax-Payer

If such a force of men are paid a living wage for their work they will usually take a great interest in it and considering that the temptation to skimp the cement or to use an inferior aggregate or to give an insufficient time to the mixing or to improperly set and rigidly brace the forms, is all eliminated, the quality of the work will, in nine times out of ten according to my experience, be far better than if let in the regular way to some of the so-called contractors.

The law requires that the preparation of plans and specifications must be done by the county engineer or some other licensed engineer designated by the board of county commissioners. In case the highway superintendent happens to be a licensed engineer the expense of making elaborate plans and specifications may be greatly reduced. A good working sketch in the hands of a competent foreman is all that is actually needed. If, as is usually the case, the highway superintendent

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is not a licensed engineer, the county engineer, though required to make the preliminary surveys and plans for the work, would not need to incur the expense that would be necessary for public letting. In either case a considerable saving may be made in this item of expense.

TABLE 1.

COSTS OF BRIDGE AND CULVERT WORK BY MORGAN COUNTY MAINTENANCE FORCES

	Name of Bridge or Culvert	Township	Span Ft.	Cu. Yds. of Concrete	Total Cost	Cost per Cu. Yd. of Concrete
1.	Smith	Jackson		18.5	$355 38	$19 20
2.	County Line	Jackson		45.0	784 87	17 44
3.	Swope	Clay	10	26.0	462 67	17 78
4.	Scruggs	Madison		12.0	222 07	18 50
5.	Camp Creek	Washington		47.5	954 27	20 10
6.	John Moore	Madison	14	71.0	1,143 39	16 10
7.	Sheets	Madison	5	29.25	406 60	13 90
8.	John Lewis	Washington	12	34.00	478 67	14 08
9.	Stockwell	Washington	12	43.5	639 17	14 70
10.	Cramer	Washington	5	31.0	394 87	12 74
11.	Magee	Washington	10	36.0	697 48	17 44
12.	Wm. Payne	Washington	10	36.0	727 04	20 20
13.	Geo. Gage	Madison	5	26.5	449 35	17 26
14.	Plunket	Brown		21.0	221 83	10 26
15.	Sellars	Brown		12.0	197 75	16 48
16.	Fisher	Ray		9.0	132 00	14 66
17.	Wheeler	Ray		7.0	145 97	20 85
18.	Wheeler	Ray	10	40.0	699 45	17 48
19.	Scudder No. 1	Ray	10	52.0	615 68	11 84
20.	Scudder No. 2	Ray	10	35.0	508 24	14 52
21.	Caldwell	Ashland		11.0	210 80	19 16
22.	Butler Creek	Ray	14	67.5	1,109 29	16 43
23.	Young	Ray	12	66.0	895 65	13 57

Average cost per cu. yd. of Concrete $16 27.

Note: Nos. 1 to 12 inclusive constructed in 1924. Nos. 13 to 23 inclusive constructed in 1925. No. 5. Cost includes removal of old stone abutments and cribbing for superstructure. No. 17. Includes cost of pipe.

The cost of giving notice in the papers, which is necessary for public lettings, will all be saved to the tax-payer.

Form lumber may be used over and over again by the labor and material plan, adding only what the character of the work makes necessary on each succeeding job. The uncertainty of a public letting makes it necessary for the contractor to figure this item for each job separately. A great deal of money may be saved in this respect during a season.

The contractor must figure the item of interest on the deferred payments, usually 20% or more until the completion of the work. This may all be saved by the labor and material plan.

The item of premium on surety bond, which the contractor is generally required to give, may all be saved.

The contractor must add what he considers a fair profit to his estimated actual cost. This may run anywhere

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from 20% to 40% on these small bridges. This is eliminated by the labor-material plan.

I see no reason why the county cannot employ skilled labor just as cheaply as the contractor. I have sometimes noticed that in regard to unskilled labor, since the contractor is under bond to perform his contract, and limited as to time of completion, that the tendency is to demand an even higher wage from him than from the county which is free from such limitations.

One more item of expense may be almost eliminated, and that is the expense of the superintendent of construction. This superintendent, on small bridges, is usually appointed for most every reason other than his peculiar fitness for superintending the construction of a bridge. It is generally for the reason of politics or more politics. I am not making this statement against either political party. I believe it is true of both. The highway superintendent having a competent foreman in charge of his bridge building may take care of this matter in connection with his other duties without incurring much additional expense.

In conclusion I will say again that local conditions and the results which you are getting by the contract system in your own counties should determine whether or not you make a change.

If you are satisfied that you are getting 100 cents worth of work for the dollar expended by the latter method, then my advice would be continue the contract system. If not, I feel that you, as in our case, will be justified and the taxpayers greatly benefitted by trying the labor and material method.

THE COUNTY SURVEYOR'S ORGANIZATION FOR FIELD AND OFFICE WORK

By H. D. Hartman,
Surveyor of Wabash County.

Prior to 15 or 20 years ago no uniform rules governed the surveyor's office. It was considered a minor office. Surveyors never got together and had no concerted ideas. One surveyor had one idea of the office and how it should be run while the man following had different ideas. This does not make for efficient engineering. The surveyor's office was created in 1851

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by constitution. Surveyor's duties in those days, while important, were few. He did not need to have diversified knowledge of engineering. Land surveys constituted the bulk of his work. The rapid settlement and growth of the state in agriculture created a demand for drainage. A great part of the state was composed of swamps and undrained land. The legislature recognized the demands of the people and passed drainage laws. The great drainage systems of the state created not only engineering problems but the county surveyor had to school himself along other lines, such as assessing of lands, knowledge of land values and benefits to be derived from drainage. The legislature created other officials such as drainage commissioners, etc., but the bulk of the work rested with the surveyor. Thus was another great duty imposed upon the surveyor.

Then about 25 years ago there came a great revolution in transportation. The gasoline motor sprang into existence over night and changed the whole scheme of modern transportation. As a result of this great automotive development, the demand for modern highways was born as well as the complicated legal and engineering systems necessary to construct and maintain them. Thus was created the last and most important duty which fell to the lot of the county surveyor or engineer.

The county surveyor should have one or more competent deputies or assistants engaged on a yearly salary basis. One is sufficient in the average county. The surveyor cannot attend to every small detail of engineering which arises in the busy season without competent help. The deputy should be able to take the place of the surveyor at any time. The surveyor as well as the deputies should be competent draftsmen.

A surveyor cannot drive stakes, run rod, chain or instrument, etc., and do them all well. He should obtain good rodmen and chainmen and hold the same men as long as possible. Get young men from high school or college and train them. Good work cannot be done by rodmen or chainmen unless they have some idea of what you are trying to accomplish.

Every surveyor's office should have office assistance, preferably a stenographer, especially in the busy season. People are constantly coming into the surveyor's office in late years seeking varied information, and they are entitled to service.

Next in importance to good men should come well kept and well indexed note books. Get plenty of data on the work. All work should be properly headed, should show dates, names of all present and notes about weather conditions. In the surveyor's office all drawings, plans, note books, etc., should

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be filed away. Copies of all reports made and proceedings in road and ditch matters as well as bridges, etc., should be kept and properly filed away for future reference.

There should be adopted in the near future a uniform system of plans and profiles to make same standard as to size and general make-up. We should also adopt a book of conventional signs for use on drawings. This would make it easier for contractors and others to interpret drawings. Counties should have a uniform datum for levels. Each road or project now has a separate datum line. Each county should have in the surveyor's office a map and record showing the details of each road and bridge in the county. The map should show data such as length, width and kind of road and name of stream, span of bridge, area of opening, whether concrete, wood or steel bridge, etc. The importance of such a record is quite evident.

Road superintendents on new work should be considered part of the county surveyor's organization, and should report to the surveyor each day by making out a daily report devised by the surveyor. The county surveyor's men should be quiet and well mannered on the work and not make wild or unwarranted statements to the people.

Work should be arranged by agreement with the court or commissioners so that the bulk of designing or preliminary work can be completed in the winter time in order that more attention can be given to construction in summer. Thus the surveyor's work is more uniformly distributed throughout the year.

THE COUNTY SURVEYOR'S ORGANIZATION FOR FIELD AND OFFICE WORK

Discussion by W. E. Morthland,
Porter County Surveyor.

The subject assigned to me is a difficult one to discuss owing to the fact that each of us is confronted by different circumstances. As regards pay, some of us are well provided for with yearly salaries while others work by the day when there happens to be county work to be done. Some of us have to work up private practice with small towns and among individuals in order to keep any organization at all. Restrictions by our boards of county commissioners and the State Board of Accounts greatly influence our organizations.

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Considering these many differences of working conditions I will merely discuss my organization as I am able to hold it under the conditions in Porter County.

I probably have an average amount of county work. We generally have from three to twenty miles of new road work. Ditches, bridges and culverts, all require varying amounts of time. County work would probably keep a small organization together provided it were steady, but it is not. Things that should be done, such as keeping up quarter-section plats, making legal surveys and preserving landmarks during construction, I find difficult to do. This is sometimes due to a lack of interest on the part of the county commissioners, but more often because of a failure to understand the functions of a surveyor. As a result, my office seeks private practice.

Our district is fast developing into an industrial center which provides much work for a surveyor. My private practice includes work as engineer for some of our small towns, surveyor for new layout and subdivisions and some general engineering. This has exceeded my county work this past year.

By combining private with county work I am able to keep a fairly respectable organization including two parties full time. By breaking in a transitman on each, we occasionally have a third field party. Either my deputy or I usually manage to keep in touch with construction and keep the county surveyor's office open to the public. By keeping on hand some map work for spare time, I have been able to keep a draftsman.

I regret that the inspectors on county construction do not work from my office.

One of my greatest difficulties is breaking our rodmen into transitmen and our transitmen into chiefs and that is because we have no sliding scale of pay for our help on county work. I am not clear yet as to whether it is the view of our commissioners or our state examiners, but it seems to stick, through tradition or something, that one field man is as good as another and that until a man can take complete charge of a party and be in every way responsible for its actions, he is not entitled to any more pay than the other rodmen. From rodmen to complete responsibility is a pretty big step to take and most of them get discouraged before they make the grade.

As I mentioned before, my office carries no salary. Possibly it should not but I am inclined to believe that if certain desirable things should be required of the office and it were required that the office be held by an engineer the counties would get their money's worth many times over by taking their county surveyors from private work as a means of livelihood and use their full time at adequate pay.

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THE COUNTY SURVEYOR'S RESPONSIBILITIES IN THE BUILDING OF COUNTY ROADS

By Homer Teeters,
Jay County Surveyor.

The success or failure of any county road that is constructed rests largely with the county surveyor. He, together with two viewers, in the case of a road built under the three-mile road law, must view and report on the petition to the county commissioners. If they grant the road, it is the duty of the surveyor to survey the road and prepare plans and specifications. He must design the bridges and culverts of sufficient size and strength to care for the needs of the road in question.

It is not only the surveyor's duty to look into the future to see that the road as designed and built will take care not only of present but of increased future traffic, but he must also have the ability to convince the viewers and tax-payers of this fact.

The surveyor must prepare his plans, profile and specifications so that there will be no question about getting the work done as intended. The engineer in writing specifications should bear in mind that his specifications will be interpreted by the inspector on the work and by the contractor or his foreman. They should be to the point and expressed in clear terms so there can be no chance for a disagreement or difference of opinion as to their meaning.

After the viewer's report has been filed with the county commissioners and the contract awarded, then the surveyor's real responsibility begins. With all of his precision in surveying, planning and writing the best specifications that it is possible to make, it will avail nothing unless he succeeds in getting the work done as he has previously planned.

The commissioners appoint a superintendent to look after the work. This superintendent or inspector may or may not be able to read blue prints or interpret specifications, yet he and the engineer must see that the work is built as specified. Regardless of the ability of the engineer, his work may be spoiled by an incapable inspector, unless he uses every precaution.

Regardless of whether the contractor is, or is not reliable, or whether the inspector is or is not competent, the responsibility of the engineer remains the same, for he must not

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fail to furnish the tax-payers what they pay for and have a right to expect.

It may be of interest to the young engineer to hear and have discussed some of the problems that come up during the construction of a road, problems that must be solved without the aid of text books or slide rule.

He may have some ten or fifteen roads under construction, everything has been going fine, he has spent a busy half day at the end of the month in making estimates so the contractors may receive eighty per cent of their contract price on work done to date. After these have been carefully checked and filed with the county auditor, the surveyor feels relieved of a great responsibility and has about decided to attend a base ball game in the afternoon, when a contractor and inspector step into the office to report that two miles of the grade on their road is now completed, arrangements have been made to start placing material on the road next day, and that it will be absolutely necessary that the grade be checked immediately.

After checking the road through the first fill and over the first cut, you find that the hill lacks eighteen inches of being down to grade on the summit, and the fill lacks from six to ten inches of being up to grade at the place where you wanted to get above high water mark. Before you have time to get this information to the contractor, you are quietly informed by the owner of the land that he thinks the grade is satisfactory, and any way he thinks it unnecessary to have the hill cut any more, and has made up his mind that if there is any way to stop it, he will not have it done.

The contractor and inspector then explain to you that as long as those along the road are satisfied they see no reason why you should not be. Furthermore, they have passed the word out that they would start hauling next morning, that stone had been shipped to the unloading station, also that the railroad company had had trouble in getting a sufficient number of cars, and if they lost these cars, there would be no chance for any more soon. Further, the manager of the stone quarry had served notice that if he was to furnish the stone this season, shipments would have to be made at this time.

The man that drives the school hack over the road gives you the information that the education of some thirty pupils will depend on whether the stone is, or is not placed on this road before winter sets in, as it will be utterly impossible for him to make his trips around the detour when the roads break up.

The postmaster may call you up and announce that the

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mail route over this highway will be discontinued unless this road is completed before a certain time. These are some of the things that will probably cause you to miss the ball game; yet they are problems that must be satisfactorily solved, and are a part of the responsibilities of the county surveyor in the building of county roads.

THE RESPONSIBILITIES OF THE COUNTY SURVEYOR IN THE BUILDING OF COUNTY ROADS

By Dave Harker,
Clinton County Surveyor.

The county surveyor's responsibilities in the building of county roads are many, but they can all be summed up in two principal responsibilities.

First of all, the surveyor must see that the road is correctly specified. The other two viewers for the road have more to do and say concerning the probable utility and benefits of the road. The surveyor is the engineering brains in the design of the road, and as such has many responsibilities in the correct design. It is not within this topic to discuss what are the proper methods as to size and shape of side ditches, types of culverts and their location, gradation of gravel or the depth and width of gravel. Whatever may be the beliefs of the surveyor, he should specify the road correctly as far as clearness and his views of engineering design are concerned.

When the road is ready for actual construction, the second of the surveyor's principal responsibilities is at hand, that is, he must see that the road is built to specifications. The superintendent of construction is appointed by the board of commissioners to superintend construction, but too often the man appointed knows little about how a road should be built. The surveyor should always take the final responsibility for the building of the road. The position of the superintendent of construction should be approximately that of an assistant to the surveyor. The surveyor is wise who assumes the responsibility in the beginning and has direction of the work, rather than to allow the superintendent of construction to run the job, and then hear the public say, "It was the surveyor's fault." No matter how hard the surveyor may try to shift the responsibility for the failure of a job to other shoulders, the public will place the credit where it rightfully belongs—upon the county surveyor.

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We built three miles of gravel road last summer under rather rigid specifications calling for gravel which would test not more than forty per cent through the quarter inch screen. The first five carloads which came in tested sixty per cent through the quarter inch screen and we rejected them. The gravel company's representative—a man from Missouri—had to be shown, so we tested it for him and he admitted that the gravel was finer than that specified. "But," he said, "you can use it anyway, for no county surveyor adheres that closely to specifications." That is a serious charge. Every county surveyor should adhere closely to specifications. If you believe that a greater per cent of fine material is desirable in your gravel, then specify it that way, but once you have specified the gradation of the gravel, adhere to specifications.

In conclusion, let me sum up what I have said in these phrases: First, say what you mean, and, second, mean what you say!

THE ECONOMICAL DESIGN OF ROADWAY STRUCTURES

By W. J. Titus,
Chief Engineer, Indiana State Highway Commission.

One of the important things which a concrete pavement slab has to do is to support heavy vehicular loads. The function of the pavement slab, as of any other structure, is to transmit these loads to the subsoil, distributing them so that they will not cause too great a load on any area of the soil. Exactly as in any other structure, these loads must be transmitted to the subsoil without any damage to the pavement slab. To design a simple beam supported on piers or abutments at each end is not a difficult matter, but at the present time, it is quite a different matter to rationally design a pavement slab resting on a continuous support throughout its length, which support is yielding to a degree which we cannot determine—in fact to innumerably different degrees within comparatively short distances.

The task seems next to impossible, but much experimental and research work is being done, by the U. S. Bureau of Public Roads and by highway departments and universities, including our own Purdue University, so that I believe in a few years, we will be able to aproach a pavement design task with something of the same assurance with which we now start on the

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design of a bridge. The situation in pavement design now is probably not less advanced than was the matter of bridge design less than a century ago. There are still many evidences of this right here in Indiana. In most old timber bridges built before the Civil War, the size of all timbers in the upper and lower chords was kept the same for the entire length of the bridge, but we now know very well that in both chords, the stresses are very much greater at the middle of the span. Likewise, in these old timber bridges, the diagonal truss members were usually of the same size in every panel, but we know that the stresses are very much greater and the diagonal members should be much larger near the ends of the spans.

We have been prone to assume that the corners of a pavement slab next to a transverse expansion joint are weaker than any other part of the pavement, but experiments made by the U. S. Bureau of Public Roads within the last year indicate that this may not be true for 90° corners and that the points showing the greatest tensile (and consequently most dangerous) stresses are found on the under side of the slab directly beneath the wheel load when that load is very close to the edge of the slab. This seems scarcely reasonable, but is apparently in accordance with both theoretical and experimental research. Recent experiments also indicate that the same wheel loads, when as much as 21" from the edge of the slab, under the subsoil conditions which existed where the slab was tested, caused tensile stresses somewhat less than one-half those caused when the load was but 9" from the edge of the slab. On the face of it, this indicates that the edges of the pavement should be thicker than other portions or that heavy loads should be kept near the middle of the slab. The latter is of course impossible.

This result was also indicated by the now well known Pittsburg, Cal., and Bates, Ill., experimental roads, which were built at great cost and tested to destruction under careful engineering control. From the data secured in these and other investigations, there have been developed the following formulas for determining the thickness of a concrete pavement slab:

(1) $t_1 = (3P/f)^{1/2}$

(2) $t_2 = 0.7t_1$

Where t_1=the edge thickness of the pavement slab in inches;
P=the maximum wheel load in pounds;
f=the allowable tensile stress in concrete in lbs. per square inch;
t_2=the thickness of the slab near the middle of the roadway.

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In Indiana, the maximum legal wheel load is 11,200 pounds. If the maximum allowable value of f be assumed at 350 lbs. per square inch, then

$$t_1 = (3 \times 11{,}200/350)^{1/2}$$
$$= 9.8''$$

and $t_2 = 6.8''$

There are, however, a good many other factors which must be considered. It is necessary to make transverse joints at certain intervals, at least at the end of each day's run. On each side of these joints will also be unsupported edges, just as truly as along the sides of the pavement slab. In some respects, the conditions will be more severe along the edges at these transverse joints, because all heavy traffic will have to cross such joints—not merely run parallel to them—and the crossing will cause the setting up of impact if there is any variation in the elevation of the surface of the pavement across the joint. So it seems certain that the edges along such transverse joints should also be thickened or otherwise strengthened —that the necessity for such strengthening may be even greater than along the sides of the slab. At the annual convention of the Mississippi Valley Association of State Highway Departments in Chicago last week, a representative of one State said they had, in their concrete pavements, for at least one season, so thickened the edges next all transverse joints, but that within a few months in nearly every case a transverse crack appeared along the line where the thickened section was reduced to normal thickness!

This indicates that there were some forces at work on these slabs which were not considered in the design. I suspect that in this case, the force was that of contraction, due largely to changes in temperature or moisture content. Without the thickened edge next the transverse joint, the slab might slide on the subsoil when contraction takes place—and in fact would do so unless the friction on the base were greater than the ultimate strength of the concrete cross-section of the slab. But the thickened edges next the transverse joints served precisely as an anchor for the end of the slab, so that it could not slide on the subgrade and could not be expected to do other than crack away from the anchored end of the slab. From this it seems that the situation will be made worse by the thickened edge next the transverse joints, unless the thickened portion be extended for a long distance in each direction from the joints so as not to serve as an anchorage to the subgrade.

To complicate the situation still more, there is the certainty that transverse and diagonal cracks will form in the slab at intervals—we do not know just what intervals. As

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soon as these cracks have opened a very small amount, so that there is no dovetailing of the broken pieces of concrete, the necessity for thickened or strengthened slab sections adjacent to the cracks will be as great as at transverse construction joints. Because these cracks are liable to occur at any point in the pavement, it seems to follow logically that all portions of the pavement slab should be thickened! This would mean of course a slab of uniform thickness and I am not so sure that this is not the most rational design which can be devised, though large numbers of states and other municipalities have recently adopted and are now using designs with thickened or strengthened edges along the sides of the pavement. But I am not ready to say that this pavement slab should have a 9.8″ uniform thickness, in view of our very satisfactory experience with a 7″ uniform thickness. All of these ideas are quite confusing, but I believe that if we do not get discouraged, avoid upholstered furniture and keep plenty of sharpened pencils conveniently close, we will, some of these days, know about what is a proper pavement design.

Longitudinal Joints

There is one design feature about which most state highway officials are now agreed—the keyed longitudinal center joint in pavements of about 18 feet in width, which is being required in Indiana's 1926 pavements. When a pavement slab is subjected to varying temperature and moisture content conditions, these changes occur much faster in the upper surface of the slab. With a dry and perhaps cool condition on the upper surface, as often occurs during a summer night, there will be extreme contraction stresses in the fibres next the upper surface, while the lower surface next the subsoil may be moist and warm, which will cause expansive forces and the slab will warp concave upwards. This warping is often sufficient to lift the edges of the slab clear of the subsoil, so as to create a heavy bending moment near the middle of the slab, due to the weight of the slab itself and of wheel loads on the edges. To use the parlance of the railroad maintenance man, the slab is "center-bound," exactly as railroad ties often are center-bound, causing the breaking of many ties when a train passes over such a stretch of track.

Exactly the opposite condition will of course exist, when the lower surface of the slab is cool and dry and the upper surface is hot and perhaps moist, causing the slab to warp convex upward and even raising the middle of the slab entirely from the subgrade. It is next to impossible to make our slabs of sufficient thickness to reinforce them against the

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heavy stresses created under some of these conditions, so there was hit-upon the expedient of making a hinged joint down the middle of the pavement, so that the two halves of the slab can rotate about this joint. The same warping condition will of course still exist for the half-widths of the slab, but the amount of warping will be very much less and the bending moments from wheel loads will probably be less than one-fourth as great. There are several types of these center joints, but there is not much choice between them from a structural standpoint, so long as the two halves of the pavement are efficiently keyed together and so held with dowel bars, that loads supported on one side of the joint will also be very considerably supported by the slab on the other side of the joint.

Contraction Joints

The feature of pavement design about which perhaps there is now most discussion is the matter of reinforcing the slab against temperature stresses and those stresses due to wheel loads and to changes in moisture content. The use of such reinforcing is with the expectation of predetermining the locations of all cracks or joints and making adequate provision for a slab of uniform strength throughout, including the edges of such pre-formed joints. It is a comparatively simple matter to develop an equation from which the spacing of such transverse contraction joints can be determined, for certain assumed conditions equating the total resistance to sliding on the subgrade for half the distance between contraction joints to the safe working tensile strength of the steel and concrete in a transverse section of the slab. This can be worked out on either one of two assumptions: (1) that the stresses in the concrete of the section shall not be severe enough to cause even half cracks, or (2) that the steel be stressed up to a safe working value, in which case there are sure to be many fine hair cracks in the concrete. There should presumably be no objection to these fine cracks, since they will be keyed together by the rough surfaces of the cracks and will be held tightly together by the reinforcing bars, so that they cannot open wider—in effect a hinged joint exactly like a keyed center joint.

Without any reinforcing bars at all, these pre-determined contraction joints should, under the first of the above assumptions, be about 29 feet apart, under certain further assumptions as to thickness of slab, width of pavement, weight of concrete and the coefficient of friction of the concrete slab on the subgrade. Under these same conditions, this spacing

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between transverse contraction joints can theoretically be increased as much as 100 feet or more, by the addition of definite amounts of longitudinal reinforcing steel. There is, however, at the beginning of this computation, an assumption which may not be in accordance with the facts, which is that the steel bars will be able to absorb all the tensile stresses in the section most highly stressed. As a matter of fact these stresses will sometimes be a maximum near the top surface and sometimes near the bottom surface, so that with reasonable amounts of steel, there will, I fear, be many cracks between contraction joints under most any conditions we can secure. The situation can, however, obviously be helped by reducing the coefficient of friction between the slab and the subgrade, so that the slab can more easily slide on the soil. In a number of instances, this has been attempted by the use of building paper spread over all the subgrade and I believe this is said to help the situation somewhat.

From the foregoing, it would seem that the use of transverse expansion or contraction joints is indicated, with some suitable plastic material in these joints to allow for expansion and contraction. A number of state highway departments, including, I think, Wisconsin, Michigan and Pennsylvania, which latter state laid more pavement last year than any state ever before laid in one year, have definitely adopted standards which require such contraction joints at regular or specified intervals. In the Indiana department, we believe that the use of these joints is indicated as an early development in concrete pavement slab design, in an attempt to prevent the unsightly cracks and the "blow-ups" which so often occur under certain weather conditions, usually perhaps at the summits of grades or near horizontal curves, but we are not convinced that the desirability of using such contraction joints has yet resolved itself into what may be termed a definite conclusion. In all arts which are in a formative stage, certain ideas may be only indications, while others may be definitely classified as conclusions—in fact many indications later resolve themselves into conclusions.

Our objections to the transverse contraction joints are chiefly from the human impossibility of making with their use as smooth a pavement as when they are omitted. It seems reasonable, too, to assume that the pavement over these joints will get rougher from year to year, due to the warping or curling action from temperature and moisture content changes, because the slab is, as nearly as I know, as sure to warp parallel to the center line of the road as transversely to it. Each time the slab next a joint is curled upward, it fails to return quite to its original position, so that it seems the joints should con-

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tinue to get higher. Perhaps this same action explains why badly cracked pavements are usually rougher than those with few cracks and why they continue to get rougher.

All of this is I think more confusing than any other type of structural design, but by just such rambling discussions as this can we look over a portion of the field and draw at least a few conclusions to guide us through a part or all of another construction season. Before closing I want to give a little time to the design of pavement concrete itself, from an economic as well as a structural standpoint. Concrete must be made of cement, water, sand and gravel or crushed stone or crushed slag. Fortunately Indiana's natural resources are such that we have within our borders satisfactory and convenient supplies of all these ingredients. If we are to do our duty in spending the public funds, these ingredients must be used in such a condition that they will give satisfactory service in a slab or other roadway structure and, subject to that provision, those materials must be used which can be most economically secured. Of these materials, the two which in Indiana are strictly competitive are washed and screened gravel and crushed, screened and perhaps washed stone.

The stone of course occurs in solid ledges and must be crushed before it can be used in concrete. To crush this stone requires power and costs money, so it is evident that, if it is to be used most economically, it must be used in as large particles as can satisfactorily be incorporated in the concrete in order to save the expense of crushing the stone any finer than necessary. On the other hand, the Indiana gravel deposits contain much fine material compared to the amount of larger pebbles. It is quite evident, therefore, that if gravel is to be used as economically as possible, there must be used as large a proportion of the smaller particles as can satisfactorily be incorporated in the concrete. It is my belief that just these assumptions were made when the Highway Commission's specifications for grading of gravel and crushed stone were prepared a number of years ago. There was the further attempt to so design the grading in both cases that the resulting concretes would be of as nearly equal strength as possible. That this result has been fairly accomplished is evidenced by the results of compressive tests made of 2427 cores of concrete taken from our pavement slabs up to June, 1925. Of these 1797 were from projects in which gravel was used and 630 were from projects in which crushed stone was used. The average strength of the former was 4650 pounds per square inch, and of the latter 4520 pounds per square inch.

Because this is the first opportunity I have had to talk to all of you county surveyors and engineers, or in fact to an-

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of you, in regard to our policy in approving plans and specifications sent to us for review, I could not refrain from outlining to you the reasons for the position we have taken in regard to specifications for these and other materials, which we believe is on the basis of equal opportunity to producers of each material, depending only on the economy with which they are able to produce and transport their material to the point of ultimate use and not at all upon any artificial differentiations between the two materials, none of which we believe to exist, so far as use in cement concrete are concerned. We hope that you will appreciate that we are not attempting to dictate to you as county officials any of the policies of your offices except as we are required by statute to set certain standards, to which requirement and standards we believe you can have no objection. We will always be glad to see you when you are in Indianapolis or near any of our district offices and to discuss with you, as I have today, any of our mutual problems.

ECONOMICAL DESIGN OF CONCRETE AND OTHER HARD SURFACE PAVEMENTS

By Frank T. Sheets,
Chief Engineer, Illinois Division of Highways.

(Note: Mr. Sheets did not present a paper. The following notes cover briefly the main points of his talk.)

Mr. Sheets emphasized that economy of design could be obtained only when pavements having a thickness adequate to carry maximum legal loads were built. He pointed to the folly of jeopardizing high class paving surfaces by inadequate foundations.

Mr. Sheets also pointed to the necessity of determining definitely by laws properly enforced the loads which may be expected upon highways or streets. He further explained the principles of design developed by the Bates Experimental road built and tested by the Illinois Highway Department, and pointed out how these principles, if properly applied, would produce pavements capable of carrying definitely determined maximum loads at minimum cost.

The great importance of building safety into highways was also discussed by Mr. Sheets. He emphasized the necessity of using curves of long radius and with proper superelevation to obtain proper economy of operation and use. An-

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other point which was discussed was the importance of location, and by a few striking illustrations Mr. Sheets showed the startling savings in operation cost which could be effected by proper location. In one specific case in Illinois where a road some 150 miles in length was relocated almost entirely throughout its length, 31 grade crossings and 30 miles of unnecessary distance were eliminated. The saving in operation to the motorists of that State resulting from the proper location of this one highway may be estimated most conservatively at $20,000,000 in a 20-year period.

ROAD DRAINAGE

By William Tonkel,
Allen County Highway Superintendent.

The importance of good drainage in the economic maintenance of highways cannot be too greatly emphasized. There are two forms of road drainage—natural and artificial.

Natural drainage is that offered by the contour of the land and the condition of the sub-soil. Sub-soil such as sand and gravel will in places provide excellent drainage, and in some places such natural conditions afford so perfect a drainage system that very little artificial drainage will be needed beyond the customary crown and shallow side ditches.

Artificial drainage is secured by the crown of the road, side ditches and sub-drains. The crown and side ditches provide the surface drainage, and the side ditches and sub-drains serve to drain the roadbed.

Many auxiliaries are frequently necessary to proper drainage, such as culverts, catch basins, French drains, paved gutters, inlets, etc. The amount of artificial drainage required will at all times depend upon the existing natural drainage.

A road surface should have a crown sufficient to drain the surface water from the road to the side ditch. It should not be so excessive as to drain the water too rapidly, thereby eroding the shoulders. An excessive crown will encourage the traffic, in order to prevent slipping, to track in the center of the road. The crown should be slightly greater on grades of 5% or over than on level grades.

Side ditches should be deep enough so that the s
of the water is well below the base of the metal an
be kept absolutely free from any loose earth or

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which may drop into them. The depth of side ditches depends upon the contour of the land and the condition of the soil itself. For ordinary purposes the bottom of the side ditch should be about 2½ feet below the crown of the road. In soils that drain very poorly and where spring water is encountered, side ditches, 2½ and 3 feet deep, with underdrains, may be required.

Underground Drains

Where the road goes through a cut, and in soil that drains very poorly, it may be necessary, in order to secure proper drainage, to install under-drains.

It is usually desirable to keep the pipe drains from beneath the metal surface for the following reasons:

1. The soil is more porous underneath the side ditch than it is ordinarily underneath the road surface, and hence the water will have greater access to a drain under the side ditch.
2. The excavation into the sub-grade when the road is built will weaken the sub-grade, frequently causing defects to develop in the road later on.
3. If the drain becomes clogged or is broken in any way, it is more difficult to repair when beneath the road metal.

Of course occasionally, it is necessary to keep the sub-drainage beneath the road metal, as illustrated by the following:

1. When the water reaches the road surface on a steep grade, by flowing from some higher elevation and parallel to the road.
2. Where the water comes up from underneath the roadbed as a spring. In such cases it may be necessary to construct a number of sub-drains before the source of all such water is reached.

Weeds should be cut to within two inches of the soil and kept neatly trimmed at all times of the year. The cuttings should be raked clear of the shoulder and ditch so as to avoid possibility of getting onto the surface and creating a soggy, slippery, dangerous hazard.

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ROAD MAINTENANCE EQUIPMENT

By Harry J. Kirk,
State Highway Engineer, Columbus, Ohio

I intend to address my remarks chiefly to public officials, keeping in mind that a goodly number of equipment men are present, of whom each and every one, in his own mind—sells the best equipment on earth, bar none.

First, I take up a question of vital importance especially to those public officials present who are executives, the matter of buying equipment.

The public official having the power to decide the purchase of equipment must be honest. He must also frequently, and with definite finality, be able to use that little word of two letters pronounced "No!"

The third prerequisite to successful purchase of equipment is accurate knowledge of what is best to do the job planned. This is chiefly a problem of fact finding—facts about the job and facts about the equipment.

My own decisions have been based chiefly on interviews with contractors, superintendents and other men who have actually used the equipment in question.

The ideal way to buy materials or equipment on public work is first to draw up detailed specifications, and then receive sealed bids from those able to furnish.

Take the case of materials such as stone, gravel, tar and asphalt. We have specifications in great detail on these. We can take bids and make awards on the low price. It is easy to make tests and see that specifications are met in all particulars.

In the matter of equipment, however, we have no specifications even for small tools that will permit us to take bids and buy on price. And when we come to large equipment the problem is still more complex.

Take the matter of motor trucks for example. Suppose you want to buy a two-ton truck. About the best you can do is to make a few general requirements as to power, capacity, body, tires, etc., and ask for bids requesting that detailed specifications be submitted with each bid. You can get a score of truck manufacturers to quote you a price and each will claim his is the best buy at the price. No two trucks will be exactly alike and there is much ground for difference of opinion as to the best "buy." It is obvious that under these conditions low price can not be the controlling factor, because the price

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each quotes is for a different article. But the public official has to satisfy himself which offer best fits his needs.

This is the big difficulty in the purchase of equipment. The greatest help is a thorough knowledge, not only of the equipment, but of the job it is going to be called upon to do.

It pays to take good care of equipment. Too much equipment is left out in the open, exposed to the weather, and at the mercy of every thief. Adequate storage should be provided during the winter months. Frequent inspections should be made during the working season and complete overhauling should be done during the winter season. It costs a lot to have a machine break down during the working season, and no money is better spent than in the forestalling of breakdowns.

Standardization of Equipment

There are many reasons for standardizing equipment. With but one make of truck in a district the truck drivers and mechanics learn how best to operate and repair it. Better service can be given because less repair parts need be carried to take care of all needs. I must say, however, that this is an ideal hard to realize on public work, especially if you have several firms manufacturing the same kind of equipment in your state.

Recommendations on Equipment

It is with great hesitancy that I take up the matter of making detailed recommendations on equipment. The thing that makes road work fascinating is its variety. Because topography and climate varies everywhere so do road problems differ in their character and the nature of the equipment best adapted to their solution.

In many of the things I am about to say you may not agree with me, because you have in mind one set of conditions and I another. I therefore, would ask that caution be used in following out the recommendations I am about to make.

I do not intend to give free advertising any more than I can help. Therefore, although I am perfectly willing to answer any questions you may ask, I must place this condition—that I will not here publicly indicate a preference between particular machines by name. If any of you care to talk with me privately I will express my views frankly, giving the reasons for my opinion.

Grading Equipment

Many states are carrying on a program of stage construction which is closely allied to maintenance work. In Ohio we completed 823 miles of this sort of work in 1925, and it has

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met with great popular approval. This operation has been carried out in outlying districts and the poorer counties where travel is not heavy. If such communities had to wait for $40,000 per mile roads they would be in the mud for 25 years hence. We have given them an all year road at an average cost of $3,000 per mile. The old road has been widened out and minor relocations made. Repairs have been made to bridges and culverts. The old road metal has been salvaged and local materials used wherever possible. On account of a large program outlined we have found it economical to purchase heavy equipment. This stage construction grading merges into gravel or traffic bound macadam maintenance. For grading operations we have found the following combinations of equipment most satisfactory.

1. In hilly country, 10-ton crawler type tractors worked in pairs, one with a twelve-foot blade and the other immediately following with a ten-foot blade grader. On this sort of an operation we prefer the leaning wheel type of grader because it is free from side slipping, it moves the earth higher and is more easily and quickly pulled out of the ditch. We prefer the track laying type of tractor in all cases because it is not so apt to tear up the road surface or get mired in bad places.

Under certain conditions in hilly country we are using gasoline shovels with ¾ cubic yard buckets on crawler type running gear. I look upon the gasoline shovel as one of the recent outstanding developments in road building equipment for rural highways. There are several good shovels of this type on the market. It is far better than the old time steam shovel for light shovel work because of its lower operating costs. Where frequent moves are necessary there is no bother with the water lines or fuel transport problems. In coal mining communities and oil well districts there is no trouble with bad water as with the steam boiler on a steam shovel.

You are familiar with wheel and slip scrapers, the latter for short hauls on small jobs and the former for longer end hauls. The wheel scraper, however, is not well adapted to stage construction operations because there is rarely room in the ditch for it to load, except on relocations.

2. In rolling or flat country other types of equipment have proven efficient. Where cuts are long and frequent turns are not necessary we have found the small model of elevating grader most valuable. With a sufficient number of trucks, Fords with gravity dumps are good, it will move an enormous amount of material at a small cost. Under certain conditions I have never seen anything quite so efficient as a small elevating grader for cleaning ditches.

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Roadbed Maintenance Equipment

Here again the type of equipment depends upon the topography. In Ohio we have everything from the flat plains, a century ago the black swamp of northwestern Ohio, to the hills of southeastern Ohio which are as rugged as some so-called mountainous districts in the eastern states.

In southern and southeastern Ohio we ar bothered with slips and slides. The road may slide away or a hill may slip down on the road. It is too expensive to move in a shovel for this sort of small work, and it is agonizing to watch a gang of men shoveling this earth into trucks by hand.

No piece of equipment has proven more valuable for this sort of work than a small crane with clam shell bucket mounted on a truck. We own a number of these in Ohio, and while we have some of the half circle swing type and some with the full circle swing type, we much prefer the latter for moving slips and slides. Our principal reason for this is that we work with the road open to traffic and the road need not be blocked with the full circle swing.

A small ditcher originally designed for cleaning farm ditches which will do light ditch cleaning has appealed to me as a good tool, inexpensive and valuable for back slipping and other operations where the superintendent or engineer gets gray haired watching laborers waste their time.

The one-man motor patrol grader is a valuable piece of equipment for shaping up shoulders.

Cutting Weeds, Etc.

The best job of grass and weed cutting is done with a farm mower having a six-foot cutting bar that will cut at any angle between 45 degrees above or 45 degrees below horizontal. A machine of this kind pulled by a good team driven by the owner who lives along the road is the best combination for a good, clean, economical job of weed cutting that has ever come to my attention. The trouble is, however, that few farmers have such a type mower and also they may be busy at other work when you want your weeds cut.

We have used several types of cutter bars attached directly to Fordson tractors. We believe, however, that the special highway mowers, preferably with cutter bar that can be raised or lowered 45 degrees from the horizontal pulled by a team or tractor and operated by a separate man, gets the best job. A team will get into places a tractor can not, thus reducing to a minimum the work which must be done with scythes by hand.

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Gravel and Traffic Bound Macadam Maintenance Equipment

I refer here to gravel or stone roads maintained by dragging. There are two problems to be solved in this operation: (1) keeping the surface smooth and (2) replacing surfacing material blown away.

In the matter of keeping the surface smooth there are many ideas. Here again this may be caused by varied conditions such as different gravels and stone, and also difference in the volume of traffic. I do not know of any one piece of equipment that will keep a gravel or traffic bound macadam road smooth. If a thin layer of gravel or stone can be maintained over the surface much will have been accomplished. High speed rubber tired traffic rapidly throws the material to the sides of the road, leaving the center bare and in condition to go into pot holes. The loose material should be kept constantly thrown back on the center of the road. The best tool I have ever seen for this purpose is the spring grader blade mounted on springs and turned to the road surface as a razor blade is to a hone. We used to mount this type of blade on trucks received from the government, and still have many so utilized, but the trucks are rapidly wearing out and we are now using the same kind of blade in place of the stiff grader blade on the one-man motor grader. This spring blade carried along the road at 10 to 12 miles per hour will do a very good job of throwing back to the center of the road and covering the surface with a uniform layer of loose material.

But this sort of an operation is not enough. The large sled drag is indispensable if you are to get a smooth riding surface. As compared with the grader blade it is the same as the carpenter's plane compared to a draw knife. These sled drags should be used every few weeks and when the surface is in proper condition to do the most good. With proper equipment and correct manipulation of materials a gravel road can be made as smooth for riding as any hard surfaced pavement ever built, and much smoother than the average built in the past.

Now let us consider the matter of replacing surfacing material. This problem may be handled in three ways.

a. It may be shipped by railroad from commercial plants.

b. Gravel may be obtained from gravel pits or stream deposits.

c. A local stone quarry may be used to supply stone.

Where materials are unloaded from railroad cars, car unloaders and trucks are necessary equipment. In Ohio we contract with trucking companies for this sort of work. Bids are taken for material per ton spread on the road.

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The working of local gravel deposits is so involved in local conditions that each location is a problem in itself. One very satisfactory piece of equipment for this sort of a job is a certain one unit gravel crushing, screening and loading plant. Material is delivered to a belt conveyor usually by a drag line. It is then elevated to screens and oversize material turned into the crusher. It is finally delivered to the waiting truck by means of a belt conveyor. No other piece of equipment equals it in performance, compactness and portability.

Recently developed equipment valuable in gravel pits include belt conveyors, bucket loaders and truck mounted clam shell cranes. Drag line outfits can be used in many places to good advantage, depending on the depth, area covered and over-burden of the gravel deposit being worked.

In some districts where there is no gravel it is possible to crush and screen local limestone. For a small operation an air compressor operating drills is very handy. For larger operations a well drill should be used for blasting holes. The best quarry arrangement is where the crusher can be placed much lower than the quarry floor. The stone may then be chuted to the crusher platform into the crusher and then elevated to the storage bin. I have seen cars with small gauge track and Fords with gravity dumps used to good advantage on local limestone quarries, depending on conditions. We prefer the gyratory type of crusher generally because it produces a more uniform size and has low up-keep.

Bridge and Culvert Maintenance

Bridge and culvert maintenance is sometimes sadly neglected, particularly the repainting of steel bridges. I have heard arguments pro and con on the use of sand blast for cleaning and the air brush for painting steel bridges, as against hand methods. I believe there is a place for both. Inaccessible places are best taken care of by the sand blast and air brush. On the other hand a better job is obtained with the paint brush on accessible surfaces. Much depends on the personal skill of the operator. The paint spray frequently causes damage to the finish of passing motor vehicles. Both methods are being used with success.

In each division in Ohio we are employing one, and in some divisions several gangs as part of our maintenance organization, exclusively on the extension of small culverts and the rebuilding of small bridges. Concrete bridge work requires experience and skill. We use concrete mixers mounted on rubber tired trailers, easily portable, and other equipment necessary on this sort of an operation.

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We have found the cement gun a valuable unit for economical repair of certain kinds of masonry abutments. Bridge and culvert maintenance is so different from other road work that I believe it deserves special attention by experienced men with adequate equipment.

Macadam Maintenance

The largest piece of equipment used on macadam maintenance is the motor truck tank distributor for applying bituminous surface treatments. There are several good distributors on the market that will handle materials, both for cold and hot application. The tendency has been to simpler design, less pipes, etc. A recent development is the use of a separate motor for pump operation. This is especially valuable on penetration work and in hilly sections.

For cleaning the road surface a good Fordson sweeper is on the market, built stronger than the old horse-drawn sweeper. This design has the broom back of the operator which is a distinct advantage.

The biggest part of macadam road patching today is with bituminous materials. Tilting drum type mixers with skip are preferred for mixing stone and bitumen because they clean easier.

I have found the small Fordson type roller, of which there are several makes on the market, a labor saver in places where there is extensive patching. It can be easily loaded into a truck and cheaply transported from job to job.

Heating kettles of two-barrel capacity are well adapted for macadam maintenance. We buy them in all cases equipped with oil burners. This feature is well worth the extra cost as it eliminates much loafing waiting for the kettle to heat up. There have been some accidents due to exploding gas from heaters, but this can be avoided with proper care.

Equipment for Repair of Concrete, Brick, Etc.

The air compressor with paving breaker is the most recent development for concrete road repair where replacements are necessary. This applies to all concrete base pavements.

The same recommendation for heating kettles as mentioned under macadam applies to concrete and brick pavement repairs.

A special air hammer mounted on wheels is the best tool we have seen for taking down high spots or raised points on concrete pavements. We have seen an attachment for the Fordson tractor with revolving grinding wheel, but this is not nearly so fast as the air hammer recently developed.

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On account of limited time I omit here the discussion of several classes of equipment such as those for snow removal, proper machinery and tools for garages, etc.

The Motor Truck on Road Repair

There is the Ford truck. It is low in first cost. In many places it could replace some of the war time junk, still called trucks, at a fraction of the operating cost. On hauls up to 3 miles it is the most economical. Over that it fails. On hills and in hard going the cooling system fails. In Ohio we equip all new Ford trucks with auxiliary transmissions. There is no use overlooking the low cost of repair parts and the ease of handling Ford trucks.

For general maintenance work I would buy a two or two and one-half ton truck, pneumatic tires all around, dump body and hydraulic hoist with full cab. On long hauls over good roads bigger trucks may be advisable, but I believe this sort of work is more economically contracted. We can not afford to buy these trucks in Ohio when haulage contractors will do the work for less than our costs. The best truck in this class, bar none, in all-round reliability and freedom from breakdown is the "Class B" Liberty Truck supplied to the states by the federal government.

New Equipment Needed

Road equipment is much better designed than it was a few years ago. Teams formerly were used much more extensively, but they have been largely displaced. Much trouble was experienced awhile back attempting to use tractors to pull machines designed for teams. While we have little of this sort of trouble today, yet there is much room for improvement in other ways.

The chief source of trouble occurs where the manufacturer's engineers do not have the practical knowledge of the work the machine has to do.

Motor truck bituminous distributors need wider tires on penetration macadam work. Better heating facilities, in the way of a burner made of metal of higher heat resisting quality and designed to secure more complete combustion will save much valuable time now lost. Provision should be made in the design to reduce piping to a minimum and to automatically heat all pipes, even the spray bar.

A street sweeper should be provided of more sturdy design than those still being manufactured and never intended to be pulled by tractors or moved at high speed from job to job.

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In general a better running gear is necessary on maintenance equipment because it very frequently must be moved and moved in a hurry. This applies to belt car unloaders, tar kettles, concrete mixers and other machines.

We are doing more and more maintenance work in the winter. This is because our roads are used more in the winter than formerly. Note the popularity of the closed car and the increased use of the motor truck in business. This means that we must provide greater protection against cold for the operators of trucks, graders, etc. For the same reason I favor closed cars for all engineers and superintendents who must drive long distances in all kinds of weather.

There is a big field for new equipment on maintenance operation on rural highways.

A central mixing plant lay-out for mixing cold patch bituminous materials would meet a popular demand.

A central mixing plant for concrete road repair would fill a need. It could be designed to set up at the railroad siding, using say a 10-L size mixer on rubber tired trailer, batch boxes and belt conveyor to charge the mixer.

Where the mixer must be placed on the road and half the road kept open to travel on concrete road repair a mixer is needed that can be turned 90 degrees for loading the skip on the pavement.

Half the labor in erecting guard rail is in digging post holes. I would suggest that in view of the many attachments made for use with a Fordson such a post hole digger might be made, using the tractor for power. In fact I know of one now being perfected. Another solution would be to design a post-hole digger to be run off an air compressor. At my suggestion a certain company spent some effort on this problem, but so far without notable success.

Conclusion

Last week in company with an Ohio road contractor I stood on the balcony of the Coliseum at the Road Show in Chicago. We were looking down on a magnificent array of road building equipment, estimated to be worth $3,000,000. I remarked to him, "What would some of the old 'side-walk' contractors say if they could see this?" The contractor ever with the point of view of his tribe replied, "I am wondering what a man would do who had it on his hands with no work to do." The moral of this story is:

"Don't tie your money up in expensive equipment unless you have work for it to do."

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Contractors must obey this rule or go out of business. Public officials must follow it or be kicked out of office.

The justification for buying equipment depends on the economy of what it will do as compared with other methods.

On public work and particularly on highway maintenance work there is another very good reason for the extensive use of labor saving equipment. Most all road repair operations are carried on with the road open to traffic. The work is done under the eye of every passer-by. The farmer, not very prosperous these last few years, is especially critical. Every time a laborer, even for a moment, rests on his shovel handle, several heavy tax-payers see him. And you know what happens. We depend upon public opinion for the support of an adequate highway program. I am, therefore, in favor of keeping the number of public employees on rural highways down to a minimum. Labor saving machinery is the best way to do this.

The volume of road maintenance and repair work on highways is growing by leaps and bounds. It offers a field of opportunity for the road equipment manufacturer and the road contractor.

The greatest loss in connection with equipment generally is the loss when it is not working. The purchaser of equipment, therefore, be he public official or private contractor must know that he has superintendents with ability and finances adequate to make that equipment earn more than it cost. I say this because no equipment can take the place of the man who has good judgment, initiative and energy to do things.

HEAVY GRADING EQUIPMENT

By S. N. Johnson,
Clinton County Highway Superintendent.

The outstanding cause of bad roads is poor drainage or no drainage at all. Road drainage is just as essential as farm drainage. The success of gravel road maintenance depends largely upon this factor.

Clinton county has 841½ miles of county roads, many of which were constructed more than 25 years ago. Very little attention was given to drainage in their construction.

Late in the year of 1924 we purchased a 10-ton tractor and a 12-foot blade grader, and began opening up side ditches on our gravel roads. About 65 miles were given just one

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round. In May, 1925, we resumed our drainage and up to November 6th we had drained 181½ miles of road. Eighteen and three-fourths miles of this total was grade or what we call reclaimed work. We also did some maintenance during this time. On the 18¾ miles of reclaimed road, ten rounds or more were made with the grader. In doing this work we follow about this procedure:

Round 1. Throw the gravel to the center of the road.

Round 2. Throw the sod off the berm to the side ditch or where it should be, cutting it as thin as possible.

Round 3. Dig a ditch in the berm, where sod has been removed, in which to bury the sod.

Round 4. Throw the sod out of the side ditch, at the same time cutting the remaining sod over the location of the final drainage ditch, turning it all back into the sod burial ditch made in the berm.

Round 5. Make the first ditch cut about 18" from the fence or property line.

Round 6. Make a second cut in the ditch by stepping the cut slightly toward the road.

Round 7. Make the first cut with a back-sloper. Sometimes a second cut with the back-sloper is necessary.

Round 8. First level is made on the berm, spreading the dirt which came from the ditch away from the gravel.

Round 9. Reverse blade and spread the dirt from the ditch toward gravel.

Round 10. Spread out the gravel from the center of the road to desired width.

During the several rounds, the tractor has traveled over the sod and loose earth so that there is very little settlement afterward. We do this work early in the season so it will become thoroughly settled before the fall rains set in.

On purely ditch work we make two rounds, as follows:

Round 1. Cut the ditch as deep as possible considering the condition of the road for drainage, throwing the dirt about a foot from the shoulder of the grade.

Round 2. Put on the back-sloper, step the ditch just a little toward the road and deepen a little more, throwing the loose dirt against and on top of the dirt and sod from the first cut. At the time this cut is made we run one side of the tractor over the dirt taken from the first cut to settle it as much as possible before the dirt from the second cut is put upon it. On this round we also use an ordinary road drag chained to the grader to level the dirt.

Early this year our district men will work this dirt and rotted sod and level it out on the berm. Care should [illegible]

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not to cut the ditches too deep where the gravel is low so that the berm will not be built up higher than the graveled part of the road.

On our reconstruction or reclaiming work the length of the road to be graded as a unit depends upon local conditions. Inasmuch as the roads while being graded are almost impassable, it is desirable to work the road in short sections so that traffic interference will be reduced to a minimum. A length of one mile is recommended as a grading unit. On purely ditch work the roads are not torn up so much and we do our work in longer sections, sometimes as much as five miles.

Equipment for this work should be of the heaviest type of 12-ft. grader with special back-sloper not more than 2 feet in length, and not less than a 10-ton or "sixty" crawler type tractor. It is necessary that the equipment be operated efficiently. A good grader operator is a skilled mechanic and not an unskilled laborer. An operator always should be chosen because of his skill in operating grader machinery.

The grading crew consists of two machinery operators who receive a total of $9.00 per day and the assistant superintendent at $3.00 per day as helper to locate drains and remove mail boxes and any other obstructions. His wages are not included in the cost, as this labor is of a miscellaneous nature.

We kept an accurate record of the cost of the work in 1925 for labor, gas and oil, not considering depreciation or interest. Our cost per mile for reclaiming the 18¾ miles was from $43.57 to $75.00 per mile, or an average of $54.00. On drainage alone for 162¾ miles the average cost was $8.60 per mile of road.

MAINTENANCE OF GRAVEL STREETS

By E. D. Canatsey,
Morgan County Surveyor.

The maintenance of gravel streets embodies a number of elements and conditions not encountered in the regular maintenance routine on county and state gravel roads.

The greatest difference is due to the use of road oil on streets. Instead of a thin carpet of loose gravel to work with the ordinary maintenance tools, we have a smooth, hard sur-

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face. Instead of the "wash-board" surface to contend with, in dry, hot weather the oiled streets break in small, round, basin-shaped holes that quickly grow larger and more numerous. We call them pot holes. This evil of the oiled street is by far the most difficult problem to overcome.

Midwinter is the proper time to begin preparing the streets for oil. We will assume that the road bed and curb ditches have been properly constructed and maintained. While the streets are frozen solid is the best time to apply a very thin layer of good gravel. Apply it over the sections that show weakness of surface, that is where the pot holes are most numerous. This gravel should contain a minimum of sand and should all pass a one-inch screen, or better still the ¾-inch screen. The metal added at this time seems to stick where applied, and as the frost leaves the road bed the new gravel bonds and keys itself into the old surface. The use of the drag during the freezing and thawing weather over surfaces thus treated will obliterate the pot holes.

We usually apply the oil in the latter part of May after the heavy spring rains. The streets should be in first class condition before the oil is applied. A slight scarifying is best at this time. Formerly in Martinsville this scarifying was done with a specially constructed street harrow. This tool will scarify an inch or two of the old oiled surface, then with a grader a uniform surface can be made. The light scarifying allows the hot oil to penetrate faster and deeper than otherwise. The oil should NOT be applied when the ground is too cold or when there is much dust.

We apply the oil with a pressure tank distributor which has an inside burner. The temperature of the oil while being applied runs from 130 to 180 degrees F. Steam is applied to the tank car about six hours before the oil is pumped into the distributing tank.

We usually oil every other street, say east and west, then every other street north and south. About a week or ten days later the remaining streets are oiled. This allows traffic to avoid the freshly oiled streets to a certain extent.

An experiment was tried two years ago on four blocks where traffic was heaviest. Following the oil tank, torpedo sand (i. e., sand that passed the ¼-inch and is retained on a ⅛-inch screen) was spread on the hot oil, just enough to kill the flow and thicken the oil on the surface. This required about 10 cu. yds. per block, the streets being 40 feet wide. This showed good results, the oil was not tracked away much and a surface was obtained that was smooth and lasting. This torpedo sand is obtained from a local gravel plant

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and is a by-product in getting out concrete material for the state.

New gravel streets usually take oil nicely the second year and can be easily maintained. With the older streets it is a different proposition. In Martinsville the oil used always runs from 50% to 70% asphalt. With the hot, dry weather and heavy traffic the aforesaid pot holes begin to show in all city gravel streets. It is useless to attempt to fill these holes with fresh gravel, as this seems to accelerate the grinding out of the holes. Light scarifying is necessary. The street harrow and horse-drawn grader is too slow and expensive.

Power Grader

The power grader with scarifier attached is a very successful tool. The machine used in our city has a ten-foot blade with the scarifier just ahead of the blade. To do light scarifying, use all eight of the teeth. If deep scarifying is required use only four teeth. The idea in scarifying the oiled street is to get enough of the oiled gravel to fill the holes. After scarifying, the blade is set at a slight angle to cast the material from the center. You will be surprised at the amount of black material the blade will gather after the light scarifying. This material will stay in the holes. The reason for setting the blade to cast outward is to flatten the crown. Most of our streets have too much crown.

The great advantage of the one-man, power grader can easily be seen. When scarifying or grading, the operator can stop at any time and back up as many times as necessary to fix a particularly bad spot in the street. By careful handling, the streets can be lightly planed with the blade and enough material carried along to fill all depressions. It is impossible to cut very deep without the danger of rolling up the entire oiled mat and spoiling the surface of the street.

When a street becomes extremely rough, it is always best to scarify the oiled surface thoroughly, then level up with the blade. The surface in such cases should be scarified to a depth corresponding with the bottoms of the deepest holes. The 1800-lb. dual wheels roll the surface down pretty well and the street soon looks as black as before. When planing the streets lightly to keep small holes filled, I prefer working from the center toward the edges, then if any excess material is left, work this back to the quarters, as this is the section that usually gets most of the wear and breaks first.

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Reshaping Streets

Sometimes we have sections of streets that need re-forming entirely. In one case I have in mind the street was arched up in the middle of the block, at the alley, about 18 inches too high. We scarified the gravel about six inches deep, then with the blade this loose material was moved to the curb in a narrow ridge. This operation was repeated over and over until all of the gravel was transferred to the curbs. Then the sub-grade was scarified and ridged with the blade in the center of the street until the proper grade for the sub-grade was reached. This loose sub-grade material at the center was hauled away and the gravel was replaced with the power grader in even layers. When the job was completed the street was rolled down and smoothed by the big dual wheels of the grader. In this particular case the gravel was removed from one block of the street, about 60 cu. yds. of sub-grade material hauled away, and the gravel replaced in 15 hours. The force employed included one man with the power grader, two teams with drivers and two extra men. This piece of street was oiled about two weeks later and remained in good shape throughout the summer.

One word in regard to oiling, as there are some who oppose street oiling. There are two points to be mentioned on this subject that prove the value of street oiling, aside from the feature of preventing dust. The first is the saving in the wear on the surface. Two years ago we left gaps unoiled about 6 feet wide across the streets at sidewalk crossings. This was to give the pedestrians a place to cross without walking in the fresh oil. These unoiled strips in some cases wore down as much as 4 inches lower than the oiled sections adjoining. This gives some idea of the amount of road metal saved on our 22 miles of graveled streets in one year.

The other point is in the matter of water saved. Just before oiling, in late spring, water is used in great waste by the people living on graveled streets to keep down dust. The water superintendent's daily pumpage report shows a marked difference in water used before and after oiling. Either of these two points shows enough gained to prove oiling worth while.

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STONE ROAD CONSTRUCTION

By E. D. Nesbitt,
Jasper County Engineer.

During more than ten years in charge of stone road construction in Jasper County, we have made some rather radical changes in our standard specifications, especially with regard to the size of stone and the manner of placing.

In making such changes we have kept in mind the original cost to the taxpayer, the cost of maintenance, and the service to be rendered, that is, the amount and weight of traffic.

Jasper County has been very fortunate in having its heavy duty roads taken over by the state, thus leaving the 460 odd miles of county roads subject to moderate or light traffic.

Before the work of construction is begun the center line of the road is marked by stakes set along the margin of the road at 500 foot intervals and plainly marked with the number of feet to the center of the road. These center line stakes are set from corner stones or other controlling marks which must conform to the lines as determined at the time of the original survey and cross-sectioning. Station stakes are also set along the margin of the road, showing the location of each station. Grade stakes are set on both sides of the road at each station. The grade stakes are driven so the top of the stakes are flush with the finished grade in the fills and in the cuts they are left above grade and the cuts plainly marked thereon.

After the stakes are placed, the first part of the construction necessary is the clearing and grubbing. I will not go into detail on clearing and grubbing, as it is pretty well understood what the requirements are to make way for a good roadbed. Then comes the work of building the grade, cutting the side ditches and placing all cross-drain pipes and concrete headers.

In building the grade, proper allowance should be made for shrinking. Care must be taken to have the finished grade conform closely to the grade line shown on the profile.

It is extremely important to so construct the side ditches that they will drain the road wherever it is possible to obtain an outlet. Also tile drains are provided for on each side of the road wherever a sufficient outlet is obtainable. We have found that the most successful method of eliminating so-called "quicksand pockets" is by the proper placing of drain tile.

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All cross-drain pipes are specified of corrugated metal and conform to the state specifications on corrugated metal pipe.

Here is a paragraph taken from our standard specifications on "Material":

> The material for the improvement shall be of crushed limestone and of the best quality obtainable and in all cases the stone must be of hard and compact texture of uniform grain. The stone must be of cubical form, broken, crusher-run stone and shall have a French coefficient of wear of not less than five (5) and pass through a ring not greater than one inch in diameter. The stone is to be tough, strong, and uniform in color. No soft, spongy stone will be allowed on the improvement.

Whenever any portion of the grade of the road, not less than five hundred (500) feet in length, shall have been completed to the satisfaction of the engineer, he shall give permission to place macadam upon such portions of the grade as in his judgment seems best. There shall be spread a layer of crusher-run limestone of not less than ten (10) inches in depth and ten (10) feet in width requiring not less than thirty and eighty-six hundredths (30.86) cubic yards of limestone per each one hundred (100) lineal feet.

The finished surface of the macadam, ten feet in width, shall have a crown of three inches and be of the form of a parabolic curve. All material shall receive a backing of earth along the outer edge to hold it in position.

The grade boards shall be set on both sides of the macadam in advance of the dumping and are not to be removed until backing and leveling up flush with the top of the same is complete.

In the foregoing paragraphs there is nothing mentioned about rolling the subgrade or the stone. Ten years ago we included extensive and rigid specifications concerning the rolling of subgrade and stone, and a lot of money was spent for rolling. But close inspection has been kept upon these roads that were built of 2½" stone base and rolled, and the maintenance has been high compared with the roads built with one (1") inch crusher-run stone.

We have observed and decided that by placing the money we used for rolling into additional stone and drain tile we are getting much more for every dollar spent.

To give you some idea of the cost per mile under the foregoing specifications I have taken the contract price on the last ten roads built in Jasper County and the aver[illegible] contract price is five thousand three hundred eleven ([illegible] lars per mile.

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ROAD MAINTENANCE METHODS

By B. C. Tiney,
Maintenance Engineer, Michigan State Highway Department.

Michigan is maintaining a 6900-mile system of state highways, which are classified by type, approximately as follows:

Gravel	3,700 miles
Macadam	700 miles
Concrete	1,400 imles
Asphalt	200 miles
Unimproved and other types	900 miles

The gravel road is naturally our greatest maintenance problem, but this type, when properly maintained and rendered dustless, has excellent riding qualities. The smoothness of the gravel depends upon the preservation of a thin cushion of loose, fine gravel uniformly distributed over the surface. This floating cover, ranging in size up to one-half or three-quarters of an inch, is moved back and forth daily by patrol graders, keeping the depressions filled.

Regular corrugations or "chatter-bumps" must be removed at intervals by heavy blading and this is best accomplished following a rain when the gravel is workable. We consider it good practice to float the loose cover to the outside edges of the road after rains and leave it there in a ridge for a day or so until the road begins to dry out, at which time it is again floated back over the surface. If the cover is left distributed over the road while wet, it may consolidate under traffic and be lost for floating purposes.

The presence of large stones in a gravel road, near the surface, adds greatly to the difficulty of proper maintenance. Until about three years ago our gravel roads were built under a specification which permitted stone up to two and one-half inches in size, but we are now using a maximum size of one inch.

The older roads were built with a high crown, making it difficult to hold resurfacing gravel on them. To correct these faults, we scarify the gravel to considerable depth, rake out the larger stone and reshape with a heavy grader. It is advisable to harrow the road after scarifying in order to bring the over-size stones to the top. After reshaping, a light resurfacing of clean, fine gravel gives an excellent surface for floating. The cost of this work, exclusive of resurfacing, is from $60.00 to $100.00 per mile and the results are very satisfactory.

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It is probably true that in breaking up this old road crust, the road is rendered less stable during the early spring break-up, but we believe that this is more than offset by the improved riding quality and greater ease of maintaining during the balance of the year. It is not recommended that a road be scarified late in the fall.

Patrol Equipment

The patrol equipment used on gravel roads in Michigan is largely motorized. The two most approved types are the truck with a spring blade attached underneath and the tractor and grader combined in a one-man unit. The truck is operated at a speed of about eight miles per hour, making a round trip on a thirty- to thirty-five-mile section daily. This equipment is used mainly for floating loose cover, although considerable cutting of the solid gravel can be done at slower speed, especially after rains. The truck is also used to carry a load of gravel for patching holes and light resurfacing of bare spots.

The one-man tractor-grader operates at a speed of two and one-half to four miles per hour, making a round trip on twelve to fifteen miles of road. It is usually equipped with a rigid blade which does heavier cutting than the truck blade. This type of machine is very efficient in eliminating "chatter-bumps" and makes a good combination with truck patrols. The tractor-grader is used with a spring blade in some of our counties and this permits greater speed in floating but less efficiency in cutting.

The heavy grader with scarifier attachment, pulled by a ten-ton tractor, is used for scarifying and reshaping. We regard this unit of equipment as almost indispensable in the reshaping of gravel roads after the spring break-up and at intervals throughout the season. One unit may be made to do service in two or three counties and the tractor used in the winter for snow removal.

Michigan's large mileage of gravel road presents a serious problem in elimination or reduction of dust. We regard dust control as desirable on roads carrying a daily traffic of 300 to 500, and as almost a necessity for traffic of more than 500.

Our practice in this work has been along two distinct lines:

First. The application of dust palliatives which afford a temporary reduction of dust.

Second. The application of bituminous surface treatments which afford a complete elimination of dust.

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Dust Palliatives

As dust palliatives, the two types of material which have been used are Calcium Chloride and Light Asphaltic Oil. We have found that any attempt to apply either of these materials in sufficiently large quantities to eliminate all dust will cause the floating gravel on the surface to solidify under the traffic. This forms a surface crust upon which the patrol graders have little or no effect, and which, under traffic, soon develops into holes. In such cases, it is necessary to scarify the surface lightly in order to restore its smoothness. If dust palliatives are applied more frequently, but in smaller quantities per square yard, they may be made to reduce the dust to such a degree that it is not objectionable to traffic and at the same time will not mat the surface or injure its riding qualities. The preparation of a surface for application of calcium chloride or oil involves a uniform distribution of the floating cover and the supplying of cover on any bare sections.

The quantities of calcium chloride recommended for application on roads having one-half to one inch of loose gravel on the surface are:

First application—1 pound per square yard.

Second application—½ pound per square yard.

For fairly heavy traffic, a third application of one-half pound per square yard is usually required. These applications are made at intervals of four to six weeks and a total of two pounds per square yard is usually ample for the season.

The quantities of light oil recommended for use are:

One-fifth gallon per square yard for the first application, followed after an interval of about six weeks by a second application of one-eighth gallon per square yard. The two applications are considered sufficient for a season.

Calcium chloride and light oil not only reduce the dust but conserve the gravel on the road. We find that roads which are constructed of gravel with a sand filler are very difficult to hold intact under traffic in dry weather and this is especially true if the road is built on a sandy subgrade. On these sections calcium chloride is of particular benefit, functioning not only as a dust palliative, but as a bonding agent to prevent raveling and to keep the gravel in a moist and workable condition for the efficient operation of patrol graders.

Summarizing our experience with dust layers, we feel that they are very essential to the proper maintenance of gravel roads; that the formation of a crust or mat must be avoided by application of the dust layer in small quantities and that the road, prior to application, must be uniformly covered with a thin layer of loose gravel.

The cost of dust palliatives in Michigan is about $300

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per mile per year. We do not wish to give the impression that they are applied to all of our gravel roads on which traffic conditions would warrant their use. Our appropriations for this purpose have never been sufficient to finance the treatment of more than about 800 miles of the 2,300 miles which our department would like to treat. Public sentiment, however, is becoming more insistent every year in its demand for dust elimination.

Bituminous Surface Treatments

A further solution of the dust problem lies in the bituminous surface treatment of gravel roads. Our practice in doing this work is very similar to that involved in the surface treatment of water-bound macadam. We have attempted these treatments mainly on gravel roads containing a high percentage of stone, thoroughly compacted, and the nearer this approaches a macadam in structure, the better will be the results of treatment. Full thickness of metal and proper drainage are important factors.

As soon as the ground is free from frost in the spring, the road is shaped with a grader and, if necessary, scarified lightly to eliminate all ruts and holes. Traffic is then allowed to compact the loose material and a true cross-section is maintained by intensive patrol work for a period of a couple of weeks or until such time as weather conditions are suitable for applying the treatment.

The surface is then swept and light tar or asphalt is placed in two applications of approximately a quarter of a gallon per square yard each. A covering material of pea gravel, crushed stone or slag is used at the rate of twelve to eighteen pounds per square yard.

We have used cold application bituminous materials entirely for first-year treatments and the bulk of our work has been done with tars. Last year we gave one road a second-year treatment with a heavier, hot application material with very satisfactory results. It would appear that the mat thus produced has sufficient body to be carried for a couple of years without re-treating, and at the same time is not so thick that it will wave under traffic.

While the idea of alternating hot and cold treatments on gravel roads has not been thoroughly tried out in our state, we have followed this practice successfully in our surface treating of macadam.

Patrol patching, following the treatment, is very necessary. More scaling of the surface may be anticipated, especially during the first year, than would take place on the average macadam road. These small breaks must be patched

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soon after their appearance, and for this purpose a mixture of coarse sand with the same bituminous materials used in the treatment, is employed. This mixture is made in the ratio of 14 to 17 gallons of bituminous material to one cubic yard of sand. The patching is handled by one man with a wheelbarrow from stock piles along the road or by a small gang with a light truck working from a central yard.

Our experience in surface-treating gravel roads would indicate that they must be treated on an average of three times in four years and the average cost per mile per year over this period, including patching, is about $850. This appears to be economical maintenance for roads carrying a daily traffic of 800 vehicles or more, and compares favorably with the cost of maintaining such roads with patrol graders, applying dust palliatives and the necessary resurfacing of gravel.

Michigan had about 122 miles of surface-treated gravel road on the trunkline system in 1925 and it is planned to increase this mileage in 1926. These treatments convert the gravel road into a higher-type surface and eliminate all dust.

We are coming to regard this method of maintenance as a desirable intermediate step between the gravel road and the pavement on heavy-traffic sections where pavement cannot be financed for several years.

In the surface treatment of macadam roads, our department has used both tar and asphalt. Competitive bids are received annually for a season's supply of these materials, based on standard specifications of the A. S. T. M. and the U. S. Bureau of Public Roads. We recommend the use of a light tar, cold application for the initial treatment and this may be followed, the second year, with a heavier hot-application tar or asphalt. With hot treatments a larger size of chip is used for cover and the finished treatment is sometimes rolled once over to embed the chips. The use of larger chips tends to stabilize the mat and prevent it from waving under the traffic.

The hot treatment will normally carry the road for two or more seasons and is then followed with a thin seal coat of light tar or asphalt.

In patching macadam roads, the shallow breaks are given a paint coat of tar and a covering of stone chips. Deeper holes are tamped full of tar cold-patch mixture, which is made up at a central yard and allowed to cure before using.

Hot patching by the penetration method is frequently used where large replacements are to be made.

In making concrete replacements, Lumnite cement or a 2% addition of calcium chloride to Portland cement is used to give quicker service to traffic.

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REVIEW OF THE WORK OF THE DIVISION OF MAINTENANCE OF THE INDIANA STATE HIGHWAY COMMISSION

By A. H. Hinkle,
Superintendent of Maintenance, Indiana State Highway Commission.

Six years ago the State Highway Commission took over a system of roads afterwards known as State Highways. To comply with the law, this system of roads reached every county seat and every town with more than 5,000 population. After the roads were designated as State Highways, the State became responsible for their construction and maintenance, including the bridges, guard rails, marking and signing and other features required to produce and maintain a system of highways that would satisfactorily and safely carry the traffic.

The development that has taken place on this system of roads in this short period of time is very marked. Although some of the roads taken over were in very good condition and have not been changed much, this can not be said of a larger part of the mileage. Many of the roads in the sparsely settled district were trails. Few through routes were suitable for traffic during the good season of the year and practically none were passable throughout their entire length during the winter, spring, or early summer.

The construction division has paved nearly a thousand miles of roads. The bad gaps in the through routes have been improved with stone or gravel when not paved. The narrow roads have been widened. Continuous maintenance throughout the year has been maintained on practically the entire system. As a result we now have a system of about 4,000 miles of state road that are not only passable throughout the year, but are as a rule in excellent condition most of the year. This transition has been brought about in the face of an increase of traffic during the six years of 100 to 200 per cent. Some districts in the state have been opened to a method of transportation that is developing them rapidly.

We have usually rated our field men by the condition in which they kept their roads. This was the greatest stimulus for maintaining a good road. The experiences of some of our men and even hardships suffered by them in the first years of the work are hardly known. One may learn of these best while chatting with them as the soldiers do, who narrate their experiences about the camp-fires.

In this brief paper, however, we will not dwell on such

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matters, but will jump from peak to peak, getting a birdseye view of some of the work accomplished, now and then dropping down to look at a detail which may be of special interest or value to those engaged in road work.

Organization of the Division of Maintenance

When the Division of Maintenance was organized in the early part of 1920 there were five district engineers and 25 superintendents. The road mileage in the state system has increased and our organization has increased to take care of this mileage until we now have 6 district engineers and 32 superintendents. On October 1, 1925, our records showed that we were employing 69 foremen, 247 patrolmen, 266 teams with drivers, 41 skilled laborers, 28 tractor operators, 454 truck drivers, 964 common laborers, 13 roller operators, and 7 miscellaneous positions, or a total field force of 2,134 men. This does not include the mechanics and their assistants in the local garages, as these are carried on the motor transport payrolls.

The division does much of its work by contract and the percentage of such work determines the number of employees carried on the state payroll. During the rush period in the late fall and early winter of 1920, we had nearly 5,000 employees on our payroll. This rush of work was brought about by the delay in our new organization getting under way, and also because of the demand to put as many state roads as possible in passable condition for the winter and spring season.

Miles of Road in the State

The work done by the State Highway Commission in the past six years is shown in a general way by comparing the lengths of different types of surface in the state system when taken over with the present lengths. The comparison shows the work accomplished by the whole Department and not merely that of the Division of Maintenance.

Type	Brick	Cem. Conc.	Bit. Conc.	Bit. Mac.	Surf. Treat. Mac.	Stone	Gravel	Earth	Misc.	Total
Miles when taken over	41.0	96.7	7.5	24.0	68.8	796.1	1,892.7	264.7	.....	3,191.5
Miles Jan. 1, 1926	68.6	933.8	26.0	172.8	23.7	999.7	1,629.0	60.9	20.8	3,935.3

We have recently compiled the lengths of all types of roads in the state by counties, classifying them as state, county and township. This is the most complete report on the lengths of the several classes and various types of road that has ever been compiled. We might say that it is the only complete report of its kind that has ever been made.

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TABLE 1-B—SHOWING TYPES OF STATE, COUNTY AND TOWNSHIP ROADS IN INDIANA ON JANUARY 1, 1926

County	Class of Road	Type of Surface											Total by Class	Total in County
		Wood Block	Brick	Cement Concrete	Bituminous Concrete	Bituminous Macadam	Surface Treated Macadam	Stone Traffic and Water Bound Macadam	Gravel	Gravel on Stone Base	Earth	Misc.		
Adams	State		0.20	0.40		7.16		18.25					26.01	821.12
	County			3.85				679.26					683.11	
	Township										112.00		112.00	
Allen	State			35.87		8.40	1.28	31.20					76.75	1,457.50
	County			45.25		15.00		312.00	384.50				756.75	
	Township										624.00		624.00	
Bartholomew	State			9.80				2.50	28.02			0.10	40.42	786.82
	County			0.30		0.60		91.90	349.60				442.40	
	Township								220.50		83.50		304.00	
Benton	State		0.48	9.73				13.70	19.18		1.00		44.09	755.84
	County							223.00	253.00				476.00	
	Township							1.00	58.75		176.00		235.75	
Blackford	State		0.60	0.50				20.60	2.20				23.90	367.77
	County			3.50	3.00			125.63	129.12				261.25	
	Township								80.62		2.00		82.62	
Boone	State			16.76					47.97		4.67		69.40	898.14
	County								611.74				611.74	
	Township								200.00		17.00		217.00	
Brown	State								19.90				19.90	331.70
	County								81.80				81.80	
	Township										230.00		230.00	
Carroll	State		0.10		0.10	4.80	0.45	11.78	26.74				43.97	892.74
	County			1.50	0.65	10.75		42.35	514.26				569.52	
	Township										279.25		279.25	
Cass	State		0.19			7.23		15.03	17.57				40.02	1,015.44
	County		0.25	6.75	0.19	4.75	0.25	105.41	457.57				575.17	
	Township										400.25		400.25	

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TABLE 1-B—Continued

County	Class of Road	Type of Surface											Total by Class	Total in County
		Wood Block	Brick	Cement Concrete	Bituminous Concrete	Bituminous Macadam	Surface Treated Macadam	Stone Traffic and Water Bound Macadam	Gravel	Gravel on Stone Base	Earth	Misc.		
Clark	State			14.05			7.10	3.10					24.25	791.64
	County							289.89					289.89	
	Township							61.50	46.50		369.50		477.50	
Clay	State			10.20				13.40	15.84	0.50			39.94	810.93
	County		2.50	0.50	0.91	0.50		28.48	377.78				410.67	
	Township								0.75		359.59		360.34	
Clinton	State		1.04	5.72					54.03		1.16		61.95	949.61
	County		6.66	20.15				34.08	780.57				841.46	
	Township								19.25		26.95		46.20	
Crawford	State							23.75			13.25		37.00	475.36
	County							125.02					125.02	
	Township										313.34		313.34	
Daviess	State			1.00					23.60	24.10	2.40		51.10	903.07
	County			4.63				63.94	308.25				376.82	
	Township										475.15		475.15	
Dearborn	State			1.25		2.85	3.40	30.05	5.53				43.08	744.87
	County			1.83				117.71	2.25				121.78	
	Township							75.25	2.00		502.75		580.00	
Decatur	State							36.00					36.00	675.90
	County		1.50	5.70		4.70		442.50	0.80				455.20	
	Township							3.80	32.00		148.90		184.70	
Dekalb	State		1.13	1.98		0.30			38.53				41.94	815.19
	County		1.00	2.75					197.00		23.25		224.00	
	Township										549.25		549.25	
Delaware	State		4.45	9.70		3.92		4.60	13.88				36.55	941.80
	County		22.20	13.00	28.60	1.50		53.60	457.60				576.50	
	Township								327.75		1.00		328.75	

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Dubois	State			13.70				0 20	3.30	24.40			41.60	
	County							131.85	17.55				149.40	737.20
	Township										546.20		546.20	
Elkhart	State		11.21	35.43		2.68			3.13				52.45	
	County		21.21	77.34		1.75	0.90		116.18				217.38	1,021.33
	Township								23.00		728.50		751.50	
Fayette	State			5.45					14.15				19.60	
	County			3.20				8.65	103.35				115.20	406.05
	Township								244.75		26 50		271.25	
Floyd	State					9.90	4.90	11.80					26.60	
	County					16.38		70.16	17.06				103.60	341.95
	Township										211.75		211 75	
Fountain	State		1.26	22.76					15.73		0.60		40.35	
	County		0.50			3.00		52.25	318 47				374.22	775.92
	Township								214.50		146.85		361.35	
Franklin	State			1.30				7.80	29.78		3.87		42.75	
	County							84.34	129.72				214.06	773.81
	Township							13.00	186.50		317.50		517.00	
Fulton	State			0.31					13.49				13.80	
	County		1 24	2.00				20.20	341.46				364.90	831.82
	Township										453.12		453.12	
Gibson	State			23.00		0.40				20.10			43.50	
	County			2.35		3.18		309.87	59.44				374.84	1,014.23
	Township										595.89		595.89	
Grant	State			6.96	0.03	4.40		10.20	21.55				43.14	
	County		5.25	3.50	5.75	20.20		99.70	593.00				727.40	915.54
	Township							2.75	94.00		48.25		145.00	
Greene	State		0.50	0.90					34.60	24.50	1.00		61.50	
	County				2.00			192.00	339.90				553.90	1,053.60
	Township										458.20		458.20	
Hamilton	State			21.10					21.77				42.87	
	County			28.63					762.62				791.25	962.12
	Township										128.00		128.00	
Hancock	State		0.75	24.74					17.87				43.36	
	County		0.25	0.90		0.50			480.18				481.83	693.19
	Township								163.50		4.50		168.00	

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TABLE 1-B—Continued

County	Class of Road	Type of Surface											Total by Class	Total in County
		Wood Block	Brick	Cement Concrete	Bituminous Concrete	Bituminous Macadam	Surface Treated Macadam	Stone Traffic and Water Bound Macadam	Gravel	Gravel on Stone Base	Earth	Misc.		
Harrison	State					3.80	3.10	22.90					29.80	1,092.55
	County							242.00					242.00	
	Township							11.00	3.00		806.75		820.75	
Hendricks	State		1.06	18.83				8.62	14.32				42.83	841.20
	County						32.29	152.58	232.71				417.58	
	Township								322.02		58.77		380.79	
Henry	State			19.61		5.30			13.45			0.44	38.80	805.75
	County			0.50					468.20				468.70	
	Township								298.25				298.25	
Howard	State		0.90	7.72	0.56			6.15	15.47				30.80	705.35
	County		1.00	4.50	5.00			57.53	537.05				605.08	
	Township										69.47		69.47	
Huntington	State							19.01	24.09				43.10	824.65
	County			8.20	4.30	1.00		122.20	374.00				509.70	
	Township							38.35	155.00		78.50		271.85	
Jackson	State			26.25				8.30	20.50				55.05	821.67
	County			11.32				4.60	558.51				574.43	
	Township										192.19		192.19	
Jasper	State							49.38	6.00				55.38	1,016.88
	County							360.25	102.75				463.00	
	Township										498.50		498.50	
Jay	State		3.10	2.20		3.10		10.35	15.30				34.05	829.42
	County		9.25	4.87				159.88	304.62				478.62	
	Township							27.00	229.37		60.38		316.75	
Jefferson	State					4.70		28.80	11.00	8.40			52.90	778.88
	County						0.50	266.18	13.30				279.98	
	Township							26.00	20.00		400.00		446.00	

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Jennings	State							39.00	3.20				42.20	
	County			0.07				251.57	31.00				282.64	834.19
	Township								33.00		476.35		509.35	
Johnson	State		0.80	15.42	1.25				4.60		4.30		26.37	
	County			1.20					415.20				416.40	615.42
	Township								154.95		17.70		172.65	
Knox	State		4.10	17.30					25.50	23.40		0.10	71.40	
	County		6.27	9.89				63.10	541.64		2.16		623.06	1,035.36
	Township										340.90		340.90	
Kosciusko	State		1.09	12.19		0.47			34.42				48.17	
	County		0.53	65.31		0.61	2.84		166.09				235.38	1,132.55
	Township								595.00		254.00		849.00	
Lagrange	State		0.30	14.12					29.57				43.99	
	County			4.50					106.21				110.71	771.77
	Township								230.88		386.19		617.07	
Lake	State			23.15	1.87	5.92		45.02				2.83	78.79	
	County		1.99	32.37	36.39	68.92	77.18	462.69					679.54	1,050 23
	Township										291.90		291.90	
LaPorte	State			18.72	0.13	28.95	0.27	27.33				4.63	80.03	
	County		5 81	8.75	15.06	27.88	41.98	244.22	96.23				439.93	1,209.01
	Township										689.05		689.05	
Lawrence	State			13.60		2.80	0.45	30.35					47.20	
	County		0 21	1.85		3.75		333.07	166.01				504.89	712.09
	Township										160.00		160.00	
Madison	State			40.69	1.35				13.90				55.94	
	County		1.25	43.35	3.50			5.00	730.10				783.20	995.39
	Township								156.25				156.25	
Marion	State	0.05	0.49	68.03	9.94	7.25		3.57	2.65				91.98	
	County		3.00	83.71	13.10	0.90		46.13	657.24		19.05		823.13	915.11
	Township													
Marshall	State		2.56	8.40		0.93		9.41	27.80	2.62	1.55	0.33	53.60	
	County				10.45			2.00	308.44				320.89	956.00
	Township										581.51		581.51	
Martin	State			6.80				8.50	4.60	8.60		0.10	28.60	
	County							104.10	7.30		22.70		134.10	512.60
	Township										349.90		349.90	

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TABLE 1-B—Continued

County	Class of Road	Type of Surface											Total by Class	Total in County
		Wood Block	Brick	Cement Concrete	Bituminous Concrete	Bituminous Macadam	Surface Treated Macadam	Stone Traffic and Water Bound Macadam	Gravel	Gravel on Stone Base	Earth	Misc.		
Miami	State			16.26				1.75	22.15				40.16	844.06
	County		0.80	13.70	4.00			12.80	465.70				497.00	
	Township								111.10		195.80		306.90	
Monroe	State					10.67		34.15	1.30				46.12	640.92
	County							292.70	10.40				303.10	
	Township										291.70		291.70	
Montgomery	State			2.35		0.97			38.91				42.23	976.40
	County		3.70	8.20		8.10		60.63	524.59				605.22	
	Township							1.50	277.09		50.35		328.05	
Morgan	State	0.10	5.25	13.57		0.50		2.30	29.10		0.63		51.45	688.50
	County							16.60	284.70				301.30	
	Township										335.75		335.75	
Newton	State			1.86				47.83					49.69	743.94
	County					0.50		372.25					372.75	
	Township										321.50		321.50	
Noble	State		8.14	14.53					37.50		2.50		62.67	863.43
	County		2.03	36.59				6.02	166.98				211.62	
	Township								213.71		375.43		589.14	
Ohio	State				1.40			5.60	8.90				15.90	194.15
	County							53.75					53.75	
	Township							32.00	2.50		90.00		124.50	
Orange	State		1.60	2.70				43.20			5.20		52.70	692.99
	County							316.04	46.71				362.75	
	Township										277.54		277.54	
Owen	State				0.40			32.52	12.20	1.00		0.10	46.22	720.49
	County							258.94	10.37				269.31	
	Township										404.96		404.96	

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Parke	State	0.06	0.10	24.69					41.88		1.20		67.93	
	County							1.00	685.45				686.45	896.68
	Township								44.45		97.85		142.30	
Perry	State							10.90	20.90	1.50	12.00		45.30	
	County							48.69	33.40				82.09	750.89
	Township										623.50		623.50	
Pike	State				0.80					29.80	0.20		30.80	
	County							70.44	53.57				124.01	729.56
	Township										574.75		574.75	
Porter	State			23.48		8.15		26.15				0.79	58.57	
	County			0.16		9.20	9.11	398.11					412.58	793.73
	Township										322.58		322.58	
Posey	State								38.80	2.10			40.90	
	County								352.40				352.40	805.75
	Township										312.45		412.45	
Pulaski	State		0.62					2.00	19.22				21.84	
	County							55.75	347.25				403.00	940.58
	Township										515.74		515.74	
Putnam	State		6.59	12.05				17.77	29.79				66.20	
	County						1.03	350.89	333.89				685.81	854.70
	Township										102.69		102.69	
Randolph	State		1.10					4.85	37.23				43.18	
	County		10.46	27.28		2.00		348.15	226.20				614.09	971.02
	Township							115.00	190.75		8.00		313.75	
Ripley	State		0.10	5.40				52.00					57.50	
	County			3.60				300.20	5.70				309.50	835.40
	Township										468.40		468.40	
Rush	State		0.30	5.40				17.70	21.25				44.65	
	County			0.08			9.40	147.07	198.50				355.05	803.70
	Township							20.00	354.00		30.00		404.00	
Scott	State		0.10	11.94				0.30	8.16	0.15	0.45		21.10	
	County			0.50				30.30	131.36				162.16	369.51
	Township										186.25		186.25	
Shelby	State			16.05				9.10	7.26				32.41	
	County			2.20				68.95	416.80				487.95	820.36
	Township								298.50		1.50		300.00	

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TABLE 1-B—Continued

County	Class of Road	Type of Surface											Total by Class	Total in County
		Wood Block	Brick	Cement Concrete	Bituminous Concrete	Bituminous Macadam	Surface Treated Macadam	Stone Traffic and Water Bound Macadam	Gravel	Gravel on Stone Base	Earth	Misc.		
Spencer	State			6.40					30.70	8.20		9.30	54.60	836.36
	County								156.66				156.66	
	Township										625.10		625.10	
St. Joseph	State			26.76	4.64							0.57	31.97	904.79
	County		0.82	89.16		26.15		0 41	184.34				300.88	
	Township								129.00		442.94		571.94	
Starke	State		0.21			3.62		43.49	11.57				58.89	724.38
	County							3.00	377.49				380.49	
	Township										285.00		285.00	
Steuben	State			9.74					24.41				34.15	593.88
	County								155.73				155.73	
	Township										404.00		404.00	
Sullivan	State		0.20	25.16				6.80		1.00	0.60	0.90	34.66	881.96
	County							185.57	370.73				556.30	
	Township										291 00		291.00	
Switzerland	State							8.70	14.10				22.80	435.05
	County							127.25	23.00				150.25	
	Township							20.25	0.25		241.50		262.00	
Tippecanoe	State		2.31	12.58					38.19				53.00	903.79
	County		2.00					10.63	648.93				661.56	
	Township								185.65		3.50		189.15	
Tipton	State			12.91					13.90				26.81	606.96
	County			2.00		1.25		18.05	555.35				576.65	
	Township										3.50		3.50	
Union	State								23.20				23.20	309.80
	County			0.50				5.30	95.80				101.60	
	Township								181.00		4.00		185.00	
Vanderburg	State			19.20						5.90			25.10	560.86
	County		1.75	10.70	5.50	23.25	24.75	191.15	62.65		1.25		321.00	
	Township								6.00		208 76		214.76	

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Vermillion	State	0.39		3.56					37.11				41.06		
	County		5.75	12.17					359.41				377.33		488.54
	Township								24.00		46.15		70.15		
Vigo	State		4.02	24.22					5.25				33.49		
	County		25.93	47.68	7.75				485.82				567.18		819.42
	Township										218.75		218.75		
Wabash	State		0.31		3.56				43.89				47.76		
	County			8.20	15.90	6.50	3.50	78.60	448.10				560.80		882.46
	Township								119.40		154.50		273.90		
Warren	State			2.64					18.30				20.94		
	County			2.60			3.85		449.17				455.62		641.54
	Township								27.30		137.68		164.98		
Warrick	State			10.10		10.60			1.80				22.50		
	County		0.70	0.75		3.20	8.75	104.80	12.60				130.80		1,000.05
	Township										846.75		846.75		
Washington	State							22.77	6.90	4.00	2.00		35.67		
	County							260.65	125.61				386.26		905.18
	Township								32.75		450.50		483.25		
Wayne	State		0.20	21.20		12.17	2.70		7.15		0.70		44.12		
	County		0.25	19.45			15.75		708.75		11.50		755.70		799.82
	Township														
Wells	State		1.17			10.81			11.40				23.38		
	County		0.75	1.00			3.00	265.77	534.68				805.20		840.58
	Township								2.00		10.00		12.00		
White	State							29.14	14.17				43.31		
	County		2.00					254.00	241.50				497.50		966.31
	Township										425.50		425.50		
Whitley	State			23.39				10.04	7.18		1.60		42.21		
	County		0.62	2.20		1.00	0.75	5.00	289.69				299.26		674.47
	Township								16.00		317.00		333.00		
Totals	State	0.60	68.63	933.78	26.03	172.75	23.65	999.71	1,439.50	190.27	60.88	20.19	3,935.99		
	County		149.43	796.74	162.05	267.03	235.83	11,296.35	24,581.35		79.91		37,568.69		73,131.25
	Township							448.40	6,327.54		24,850.63		31,626.57		
Grand Totals		0.60	218.061	,730.52	188.08	439.78	259.48	12,744.46	32,348.39	190.27	24,991.42	20.19	73,131.25		

Compiled by the Indiana State Highway Commission, Division of Maintenance, January 1926.

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There is a tendency for the counties to take over more, if not all, of the township roads. While one of the incentives for this is to get a greater portion of the gas tax, this transition will no doubt result in better and more economical road maintenance in many of the counties.

The state should no doubt take over more miles of county roads. The Federal Highway Law permits Federal Aid on 7% of the roads of the state. Our new compilation of all roads of the state shows a total of 73,111 miles. This would permit Federal Aid on 5,118 miles. Certainly this is the minimum that should be in the state system. However, the larger the mileage that is maintained, the less the paving that could be contracted each year. This factor **must** be recognized in considering the greater mileage.

Activities and Responsibilities of the Division of Maintenance

The activities of the Division of Maintenance are many and varied. One who thinks casually of road maintenance seldom realizes the great variety and classes of work carried on today in maintaining a state-wide system of highways, in safe and suitable condition for traffic all seasons of the year. Of course, the larger part of the work consists in keeping the road surface smooth and suitable for traffic. However, some of the other work is quite as important, if not on such an extensive scale.

The gravel and stone roads must be coated with metal and systematically dragged; the cracks and joints in the concrete and brick roads must be filled with bituminous material; small holes and depressions in these two types of roads are patched with the same kind of material; parts that are broken through to the base must be replaced with new concrete; the bituminous roads are patched with bituminous material and maintained with surface treatments; shoulders and ditches must be sodded and maintained; ruts along the edge of the pavement filled with stone, slag or gravel; weeds and grass must be cut; snow must be removed from the surface to make them passable for winter use; the drainage systems, both surface and underground, must be kept free from obstructions so they will operate; old and narrow culverts must be extended or new ones of proper length installed; and the old steel bridges must be refloored and repainted from time to time. As features of safety, to take care of modern traffic, guard rails must be built and maintained; these, together with headwalls and other obstructions along the road, should be painted white, or whitewashed from time to time; narrow fills must be widened; sharp curves reduced; and, last but not least, an effective system

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of signs and markers installed to guide traffic and aid in preventing accidents.

No small part of the responsibilities of road officials is keeping the right-of-way clear of undue encroachments by the property of public utilities, such as poles, tracks and other obstructions which are frequently erected so close to the traveled way as to be a great source of danger. A constant warfare must be waged against oil pumps, filling stations, "hot dog" counters and fruit stands, which are continually installed too close to the traveled way. They are a source of great danger because of insufficient space in front of them to accommodate parked machines without interfering with traffic.

It will thus be seen that the work of a highway maintenance organization is not merely the dumping and spreading of gravel, as one high official ignorant of road work, one time expressed himself. If the road maintenance organization is doing its duty, it must function in all the above features. While it is all the time looking in one direction, fighting for its rights which are rights of the citizens, it must at the same time be looking in the other direction, showing a glad hand and a friendly smile to that ever-complaining class of citizens who think the highways are not in such good condition as they should be even though they themselves have never done a single act in all their lives that contributed to the provision or upkeep of a better road.

The responsibilities of the County Highway Superintendents, in maintaining a system of county roads, involve not much less difficulty than the maintenance of a system of state roads.

Accidents on State Highways

The Maintenance Division attempts to make a report on a blank form for this purpose, of all accidents occurring on the state highway system. These accidents are reported for statistical purposes with a view of learning, so far as possible, the cause of accidents. It is hoped that every means possible may be used to reduce them. The following table shows as nearly as our field forces can secure the information, the data concerning these accidents. We do not permit these accident reports to be used in damage suits. We believe that our men would hesitate to furnish their best opinion of the cause of accidents if they knew their statement would be subject to public inspection and possible legal action against them if they were not able to prove their statement.

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The following is a summary of the accident reports for the past five years:

COLLISIONS

Collisions	March 1, 1922 to Sept. 30, 1922	Oct. 1, 1922 to Sept. 30, 1923	Oct. 1, 1923 to Sept. 30, 1924	Oct. 1, 1924 to Sept. 30, 1925
Total number accidents reported	157	332	370	654
Collisions with other machines	49	109	160	302
Collisions with Railroad trains (Steam)	4	16	6	19
Collisions with guard rails	5	14	15	17
Collisions with bicycles	1	0	0	1
Collisions with culvert headwalls	7	9	11	14
Collisions with telephone poles	7	21	12	33
Collisions with wagons	2	11	6	7
Collisions with electric cars	1	6	5	11
Collisions with fences	8	12	12	21
Collisions with animals	2	7	8	5
Collisions with bridges	5	20	30	40
Collisions with miscellaneous objects	20	48	14	22
CAUSES OF ACCIDENTS				
Fast driving	99	140	181	335
Steep grade	8	14	21	28
Sharp curve	41	51	33	78
Lack of guard rail	8	26	21	22
Wet surface	3	13	16	28
Deep ditch	5	15	13	27
Intoxication	23	25	40	66
Glaring headlights	9	17	25	54
Narrow roadway	29	59	41	45
Obstructed view	9	29	24	47
Miscellaneous causes	25	37	14	37
Deaths and *Injuries* from these accidents were reported as follows:				
Accidents reported	157	332	370	654
Deaths	30	38	50	103
Injuries	133	196	255	529

Every effort is being made by the highway commission to eliminate from the state highways those physical conditions which contribute to accidents. This past year, the Maintenance Division alone has eliminated 12 grade crossings with railroads, by relocating the highway. The importance of eliminating these crossings on our heavily traveled roads is demonstrated when we learn, that of the 103 accidental deaths on the state highways this last year, 37 deaths, or over one-third, were caused by accidents at grade crossings. Frequently it is found that a grade crossing can be eliminated by relocating the highway for a much less expense than building a subway or an overhead. Many times the only opposition to such elimination comes from the few residents who live along the old location. It is desired that every county official will use his moral influence, although his county may not be able to help financially, in bringing about the elimination of grade cross-

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ings. **Certainly no road official should be guilty of lending aid to the perpetuation of this form of murder, for such it might be called, when the crossing can be eliminated at a nominal expense.**

Work Accomplished by the Division of Maintenance in 1925

The work of the Maintenance Division is distributed over about 4,000 miles of road and is continuous over this mileage throughout the year. Hence, this work is so scattered that the average citizen does not realize that the total aggregate of work done is so large. This is best brought home to us when we examine a summary of the work done, materials used, etc.

Our records show that during the past year, besides maintaining the entire 4,000 miles of state roads and bridges thereon, this division completed the construction of 24.9 miles of bituminous macadam, 19.9 miles of stone road on an earth foundation, 9.3 miles of gravel road on an earth foundation, rebuilt 18.3 miles of old road as a new gravel road, and rebuilt 66.6 miles of old road as a new stone road.

In the regular routine of maintenance work 106.5 miles of road were given a surface treatment of bituminous material.

During the year this division constructed 61 new bridges, installed 474 new pipe culverts, 48 box and slab top culverts, and 231 pipe culverts were extended. Nearly 4½ miles of guard rail was constructed, eighty temporary bridges aggregating a length of nearly a half mile were built to accommodate traffic around bridges under construction.

During the year the division used nearly 1½ million tons of stone and gravel, ⅞ of a million feet of lumber, 1¼ million gallons of bituminous material and 3¾ miles of culvert pipe.

Expenditures

The following is a statement of the expenditures incurred by the Division of Maintenance since its creation:

SUMMARY OF TOTAL EXPENDITURES FOR SIX YEARS ENDING SEPTEMBER 30, 1925

Year	Miles Maintained	Paid Out During Fiscal Year		Total
		For Maintenance	For Construction	
1920	3,200	$836,380.20	.....	$836,380.20
1921	3,200	2,361,300.19	$1,809,499.60	4,170,799.79
1922	3,280	1,641,761.44	824,247.90	2,466,009.34
1923	3,819	2,096,048.29	863,043.36	2,959,091.65
1924	3,916	2,579,251.92	1,356,729.49	3,935,981.41
1925	3,944	2,127,774.09	1,647,617.83	3,775
Average for six years	3,560	$1,940,419.35	$1,083,523.03	

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WHAT'S AT THE END OF THE ROAD?

Abstract of an Address Given at Road School Banquet
By Edward C. Elliott, President, Purdue University.

The deep sub-foundation of sentiment, of sense and of science, upon which this Purdue University has been erected, were laid by a courageous and far-sighted generation of men. These pioneers, breaking through the ancient frontiers of human privileges, did not, and could not, vision today's far flung development of the extraordinary proposal **"to promote liberal and practical education of the industrial classes in the several pursuits and professions of life."**

This original mandate has produced throughout the United States a group of institutions, of which Purdue University is a proud representative, wherein there is a keen consciousness of responsibility for being what their founders intended them to be. This, expressed in the language of our day, means that Purdue University has not served its full purpose until all of the people of the state, of whatever class or occupation, have come to realize that the University is a dependable and sympathetic agency, always at their disposal, to aid them in meeting those needs that determine the satisfactions, the happiness and ideals of the life of the ordinary man.

It is from some such philosophy as this that those serving Purdue University derive a feeling of gratification from such educational enterprises as is this Road School. This school is one of the signally important units of the scheme of practical education demanded by practical modern life. The teachings carried on here, directly and indirectly, influence every man, woman and child in the state; and many thousands who live beyond the borders of Indiana.

Nowhere in the history of the world is there a more dramatic story than that found on the pages recording the conquering of that one-time wilderness we now know and cherish as the United States. The stages of exploration, of settlement, of unification and nationalization of this conquering epoch may be written around the thrilling work of the path builders. Civilization has traveled a romantic journey from the wild game track and the Indian trail to those swift, straight, and solid highways of commerce and communication which we possess today. The Constitution was but a blue print of a nation yet to be. The builders of the roads, the canals, and the railways gave practical reality to the union, one and indivisible.

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On such an occasion as this one cannot but feel himself in the presence of new pioneers who are building new roadways for the new civilization already upon us. The modern highway has suddenly assumed a tremendous economic, civic and aesthetic significance for the American people. If our national greatness and our national unity are to be measured by the quality of American genius for opening and smoothing new lands of travel and of communications, then great new tasks are now ahead of us.

As the successors of the first trail makers, the diggers of canals and the creators of our railways, the crafts and the professions you represent are to exert an influence for good or harm upon every firm, every factory and every home in the state.

Geographically we are one land. Socially and humanly we still have great distances to go before we have become a people of that singlness of purpose upon which our final destiny rests.

All live and forward-looking citizens of Indiana have, I am sure, a deep satisfaction from the progress that has been made during recent years with the road building program of the state. To be sure this program has cost, and will continue to cost, great sums of money. And what appeals to the mass of our people is that this program has been accomplished without heavily mortgaging the future of the state with bond issues. The state has not gone into debt for its new roads even though the owners of many roadsters have acquired mortgages which they are unsuccessfully trying to burn up with gasoline.

That we need the good roads we have there can be no doubt. That we are going to have more and better roads than we have, there can likewise be no doubt. Yet there are some serious minded ones who are beginning to ask questions of consequence. How far will these roads make for a fundamentally better state? How much better off will be the individual citizen of the state when we have forty thousand miles of state highways instead of the present four thousand? In other words, how far will all these new roads make for the permanent solidity and development of our state?

We rightly assume that the roads being built and projected will make for better agriculture. Will these same roads make for an aggressive constructive citizenship determined to promote the best interests of the best rural life?

We properly conclude that the new road program clears the way for certain business prosperity. Will this same program produce better government?

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We know that the people of the state want a better and more extensive road system for pleasure riding. Will these people, who already spend not less than three hundred millions of dollars for such travel be willing to spend in taxes as much as one-tenth of this amount for the further improvement of our state schools and our state parks?

These are some of the serious questions which those whose duty it is to think for the future as well as live for the present, are asking. Unless this great modern public undertaking of road construction shall produce something more than those profits that make for material prosperity; unless these roads furnish something for our people besides the means of speed and pleasure; unless they become a new agency by which men come to know and to understand one another better; unless they become the threads by which we are bound more securely to our common heritage of duties and responsibilities, then I say to you that we shall have spent our substance in vain, and that the roads we build today are leading to the land of nowhere, instead of the land of our dreams and our hopes.

Will hard roads make for a soft civilization is a fair and open public question.

ADDRESS OF TOASTMASTER AT ANNUAL ROAD SCHOOL BANQUET

By Prof. W. K. Hatt, Head,
School of Civil Engineering, Purdue University.

On behalf of Purdue University and the School of Civil Engineering I desire to welcome to this banquet the members of the organizations constituting the Twelfth Annual Road School, namely: The Indiana State Highway Commission, the Indiana County Highway Superintendents' Association, the Indiana County Surveyors' and County Engineers' Association, and the City Street Commissioners' Association of the State of Indiana, including County Commissioners, City Engineers and Contractors. The members of these associations are public officials of this state and in like manner to the Purdue Faculty are dedicated to the service of the state.

For the first time this year, through the co-operation of the School of Electrical Engineering, these public officials assembled in this meeting are part of a much larger invisible audience reached through the radio broadcast.

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The purpose of this Road School, conducted by the School of Civil Engineering as a part of the Engineering Extension of the Engineering Schools, is to discuss the serious problems of highway transportation in this state—it is to mobilize the growing fund of information obtained by individuals who have solved successfully their local problems. A program has been arranged by Professor Petty in co-operation with the committees of the associated organizations in which the more important topics are presented by leaders throughout the state, and discussed by the assembly. In this way abilities of the many members of the Road School move upward with the rising level of knowledge and technical accomplishments of their fellows, and they return home and transmit new principles and now methods to their assistants and to their constituencies. With stiffer determination to fight for what they know to be right against all uniformed criticism, or that arising from the interests of individuals.

The sessions have a serious purpose, and one has only to look into the faces of the 400 delegates assembled at the sessions to realize the close attention given to the discussions and the vital interest of these delegates in their duties. The usual fringe activities of conventions are absent, namely: elaborate exhibits of producing organizations and the entertainment functions which are likely to divert the attention of the delegates from the sessions of the school. In other words, this Road School is at one in the methods and purposes of instruction at Purdue University.

It is not to be thought that the Road School started full grown at the beginning. It is now a going concern, but the present successful organization was only reached after a process of trial and error beginning in 1913 with a rather ambitious program of two weeks instruction for all the public officials who have to do with public works in the state. The growing seriousness and complexity of road problems naturally led to the special attention given to these matters in a Road School in 1915. At this time the position of county highway superintendents was not firmly fixed. There was a period when many bills were introduced in the legislature to abolish this office. We are glad to recognize the fact that the increasing efficiency and the success with which these county highway superintendents have accomplished their tasks has firmly entrenched this office in the minds of the public. Such complaints as may have occurred have come from the individual lack of success of a single county highway superintendent rather than the action of the body as a whole. Purdue University ventures the hope that the quality and action of the Road School has served to advance the work of the county

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highway superintendents and through them to bring about a more intelligent and economical maintenance of our county road systems. There are 92 of these superintendents, with about 1,656 assistants and over 3,000 temporary employees.

It must be remembered that while the acute problems of transportation occur on the heavily traveled state road system, comprising approximately 4,000 miles of highway, yet these county road superintendents have to do with approximately 35,000 miles of our roads. It would surprise many of our citizens to know that individual county highway superintendents spend over $100,000 a year in taking care of road surfaces. Expenditures by counties vary from $10,000 to $300,000 per year, totaling about $7,000,000. Therefore the county highway superintendent is an important public official, and should receive the co-operation and intelligent assistance of business men and others interested in our roads. Those of us who have been in contact with the Road School since 1915 believe we have observed a growing sense of importance of his job on the part of the highway superintendent and a devotion to his task which leads him to come back to this Road School and find out the best there is to know, in order that he may apply it to his local circumstances.

Indeed the growth of ability with the increasing seriousness of road problems is not confined to the county highway superintendents. The State Highway Commission was at first built on unsettled foundations. It has grown in outlook and character of organization as our road situation developed. It is only necessary to refer to the increasing load on the road until now some twenty millions of motor vehicles in the U. S. are breaking down and wearing out those road surfaces which were designed for a much lighter service. Indiana is the link that connects major lines of transport east and west, north and south. Mr. Sheets, Head of Department of Highways of the State of Illinois told us in meeting the other day that in spite of the years of study and hundreds of thousands of dollars spent in scientific investigations in Illinois to determine the design of road slabs they were still seeking answers to many of their problems.

Since this meeting is one of public officials of the State of Indiana charged with public duties and representing a wide constituency, and not, as so many of these conferences a grouping of private citizens, it follows therefore, that the School of Civil Engineering of Purdue University, which has been, and still is, a training school for state officials having to do with public works, is, in this Road School merely carrying out on a different level the process applied to the students registered

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in the school curriculum. Some 300 of the alumni of the School of Civil Engineering and many others who have had instruction in the School of Civil Engineering are employed now in directing or building roads, bridges, and other structures of this state. They will be found on the staff of the State Highway Commission, the Department of Conservation, the State Tax Board, and they fill positions of county engineer, county surveyor, county road superintendent and city engineer.

County Surveyors

Our friends, the county engineers and county surveyors who were with us in 1913 and have been attending the Road School individually since that time have now joined the Road School officially. A law was passed at the last legislature similar to the law provided for the county highway superintendents directing these county engineers and county surveyors to attend this school at Purdue University and providing for the expenses per diem and subsistence.

The office of the surveyor is a most important one, as the county surveyor is responsible for surveys, plans and specifications for all county and township roads, plans and specifications for bridges, surveys and plans for drainage systems and many other duties of equal importance. A technically trained engineer can save the taxpayers of a county considerable sums of money during his term of office due to the greater efficiency and ability in this line of work.

Eighteen Purdue men are now county surveyors over Indiana, and are among those attending the Purdue Road School. All of these activities of the Road School are finally expressed in the receipt by the taxpayers of a dollar's worth of construction and maintenance for a dollar's worth of road taxes.

It is the engineer who stands for the public in matters of plans, materials and construction. He must fight for what he believes to be right in his informed opinion. He may be defeated by higher officials whose business it is to express the final opinion, but up to that time he should carry with him the determination of his convictions.

At the present time the engineer needs special study and access to sources of reliable information to enable him to decide between the conflicting testimony of representatives of producing interests who present only a partial view of a problem. I refer to the growing practice of industry in establishing technical staffs that are a part of the overhead organization for the promotion of the use of various products employed in engineering constructions. These staffs are not composed of

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the ordinary type of sales engineer, but are technically trained men coming up through research and study. They have been students of general problems. For instance, the lumber interests, the burned clay interests, the Portland Cement interests, the brick interests, the sand and gravel interests, the crushed stone interests and a number of others have been able to attract to their organizations men who have been associated with research and intensive study of difficult problems of technology. Their researches in the field, their duties, are of a highly involved nature. The validity of their conclusions is only to be determined by analysis of underlying conditions of the experiments that but few are able to make. I say the engineer of the present day is in a difficult position trying to reconcile conflicting evidence or to satisfy himself of the conditions under which experiments or tests have been made, and which are referred to his judgment. This is all the more reason, therefore, why he should devote himself to study and come in communication with his fellow craftsman and engineer in associations of this kind where there may be a free exchange of information and judgment.

Indeed controversies between rival producing interests may become so acute as to delay needed improvements.

I welcome the free expression in open meetings of these controversies. Differences of opinion and controversies become more acute when talked of under cover—a matter of innuendo, of backstairs gossip. If men attempt to settle their differences of opinion in open meeting, they will find that many disputes are entirely unnecessary, misconceptions are removed, and that a common ground of action will be found. A most advantageous application of any one material or machine will then be determined and unnecessary friction, which engenders heat and is expensive, will be eliminated from the wheels of industry. Industry itself will be on a firmer basis.

So much, therefore, for the setting of this Road School. The whole picture is one of reduction of cost of transportation. These transportation costs amount to one-third of the general cost of production in industry.

These men assembled here at the Road School are the busy bees whose toil creates the honey which our motorists enjoy on good roads, making their life sweeter, easier and more enjoyable by eliminating tire changes and reducing garage bills. It is a long way from the beginnings of road construction in 1816 when a man named Macadam changed the whole theory of construction of roads with his idea that a stone going into a road surface should pass through a 2½ inch ring.

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But tonight we are assembled not for detailed instruction, but to enjoy a rest from schooling.

"The wisest men that e'er you ken
have never deemed it treason
To rest a bit, to jest a bit,
And balance up their reason,
To laugh a bit, and chaff a bit
And joke a bit in season."

PATCHING AND RESURFACING CITY PAVEMENTS

By D. B. Davis,
City Engineer, Richmond, Indiana.

City pavements are structures which are subjected to very great abuse. Consequently they must receive considerable attention and repairs to keep them in a serviceable condition. The causes which contribute most largely to their deterioration can be defined as those due to foundation defects, surface defects, presence of street car tracks therein and utility cuts.

The cuts in pavements made by utility companies cause greater distress and inconvenience to the official and the traveling public than any other. Although efforts are made to get a sufficient number of service pipes laid prior to laying of the pavement, the growth of cities and business constantly necessitates the laying of additional mains and service connections. This is a temporary inconvenience and should not be discouraged, but rather it should be so regulated that repairs can be made quickly and efficiently.

For the city to properly maintain its pavements, it is necessary that it have complete control over all excavations and replacements. If complete responsibility is centered on the city authorities, they may then receive the censure for negligence or likewise may receive the credit for strict attention.

In Richmond, Indiana, such responsibility is placed upon the city by ordinance, the city refilling all trenches and replacing the surface with its own forces.

In this connection, it is essential to good business that costs be kept of all repair work. This may be done effectively by means of the usual work-order system. In this way relative

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costs can be obtained for repairing cuts in the various types of pavements.

The efficient repair of pavement requires adequate equipment and tools. Considerable saving may be effected by using modern methods and modern equipment.

For patching, the Richmond street department has an outfit consisting of a Fordson Tractor pulling a two-wheel trailer wagon, having a capacity of 2½ cubic yards. This wagon was constructed in the city work shop. The body is of wood, resting upon a low wheel trailer support with the sides of the bed hinged at the third point, to better facilitate the removal of material when the bed is partially empty. Attached behind the trailer is a tar heating kettle. It has a warming rack under the hood for an extra barrel of tar. Two men, the driver and a helper, constitute the working force for each patching outfit.

Methods

When an excavation has been made in any pavement and the trench ready for refilling, the city is notified by the party making the service cut. The filling is then replaced in layers and thoroughly tamped. If it is in saturated clay or other soft material, it is replaced by gravel. This is essential if a firm sub-base is to be secured in any reasonable length of time.

In gravel and macadam pavements, after the earth is replaced, the old surfacing material is used on top. Care being used to leave it level with the surface of the surrounding pavement and not heaping it up to allow for future settlement. The trench will no doubt settle somewhat, in which case it should be refilled until it is ready for the placement of the permanent surface patch. To leave a trench heaped high, without adequate red lights, is negligence in this motor age.

In case of trenches in the business district, where there are plate glass show windows, no temporary surfacing material should be used which contains particles which can be thrown through the glass by passing autos. We have found that a layer of asphalt is most effective for this purpose. Its cohesive character tends to prevent the dislodgment of any loose particles and gives a smooth riding surface while the trench is adjusting itself for its permanent patch.

In placing the permanent patch on trenches in a surface treated gravel or macadam pavement, certain requirements should be met. The top material should be removed to the required thickness of three inches. If there is a lack of sufficient foundation material beneath this thickness, it is pro-

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vided in the usual way. For permanent patch, coarse stone is thoroughly tamped into the trench over which 1½ gallons per square yard of Tarvia X is uniformly poured. Over this is then spread a sufficient amount of ¾ inch stone chips to completely fill the voids and leave a slight excess. When these chips are tamped into the coarse stone, ½ gallon per square yard of Tarvia X is again uniformly poured over the stone and especially along the edges of the patch. Over this second pouring, a light layer of coarse sand is spread. Particular care is used to keep the patch level with or slightly below the surrounding pavement.

In patching small depressions in surface treated gravel or macadam streets, a somewhat different method is followed. After the depression is thoroughly swept free of all dust and foreign substance, by a steel or stiff fibre broom, a light coat of Tarvia X is sprinkled around the edges of the patch and clean ¾ inch stone chips are spread, leveled and tamped smooth. A light weight straight edge is useful in testing the finished tamping to determine if it is above the surrounding surface before the tar is poured over it. For a finish, a light sprinkling of sand is applied.

Gravel or macadam pavements which have not been surface treated should not be patched with bituminous materials, as these bituminous patches will after a short while stand up like islands in the street, due to the surrounding pavement wearing faster than the patch.

Patching Pavements

Rock asphalt is a material, which we have found, lends itself readily to patching various types of pavements. It is a material composed of fine sand intimately mixed by nature with from 7 to 9 per cent of bitumen. This material has the advantage of being easily stored for future or constant use, without losing any of its inherent qualities or without the need of mixing other materials with it. We have used it for patching concrete, sheet asphalt and brick pavements.

Depressions in concrete or brick are first swept clean, the surface painted with asphaltic cement and the rock asphalt tamped or rolled into them. The level of the rock asphalt should be left at least three-sixteenths of an inch high to provide for the compression which traffic will ultimately give it.

To patch sheet asphalt, the old surface material is cut out completely as in repairing with sheet asphalt. The sides of the patch are made rectangular in shape with the thickness of the old surface cut vertical. After cleaning out all foreign matter, the edges of the old pavement are painted with liquid

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asphalt and the rock asphalt spread and compacted as for repairing concrete or brick.

To secure a smooth job, it is essential that the rock asphalt be pulverized into as small particles as is possible by means of raking and no lumps should be left on the surface. In cool weather this pulverizing can be materially expedited by warming the material before spreading. Our heater, which was designed by the street commissioner, is a double sheet iron pan with sides, mounted on low iron wheels, with a stack at one end. A small fire is maintained under the heating surface, upon which is deposited the lumpy rock asphalt. An attendant keeps the material stirred with a rake until the lumps are all broken when it is wheeled or shoveled into place in the patch. The warmed material resembles sheet asphalt surface mix, crawling and full of life. Constant stirring will prevent burning while warming.

Cuts made in brick pavements are replaced with brick. A substantial foundation composed of 8 inches of Portland cement concrete reinforced with wire mesh or rods is laid 3 inches wider than the trench. This is to furnish support for the slab. Upon this is placed the sand bed and the brick in the usual manner. The joints being filled with asphalt or tar.

Cuts made in concrete pavements are likewise replaced with concrete. Formerly this was considered impossible, but now is done very successfully if but a few details are observed. The edges of the old concrete are thoroughly cleaned with water, using a wire brush. This cleaning should not be slighted in any respect. A thin paste of rich mortar is then brushed over the cleaned surface with an old broom. Before the surface of the edges have dried, the concrete for the bulk of the patch is poured, tamped and finished as for concrete pavements. The important item is to trowel the edge of the patch where it meets the old pavement, in such a way that there will be little chance of raveling. The patch should be cured to prevent rapid, excessive shrinkage. The use of quick hardening cement is fast coming into use for street repairs and is especially suited for patchwork such as this.

Cracks in concrete pavements should be repaired immediately after they become of such width that liquid asphalt or tar can be poured into them. When cracks in concrete pavements are not properly filled, traffic soon ravels out the edges until they become unsightly. Concrete pavements should be thoroughly inspected in the fall of the year and the repair work finished before cold weather.

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Our experience in patching pavements has taught us the following fundamentals which we endeavor to have the workmen follow:

Bituminous patches on unsurfaced treated gravel or macadam have proven unsatisfactory.

It is better practice to replace pavements over service cuts, using same type materials as the original pavement.

In pouring a bituminous patch, to use sufficient material to coat the particles without making it "fat."

Paint-coat the surface of old concrete or brick where rock asphalt is used in resurfacing.

Observe the little details of construction which have been evolved from the experience and experiments of others. Do not treat them as being inconsequential or unnecessary. They are the result of the failure and success of others before you. Profit by their mistakes.

Resurfacing City Pavements

Most modern city pavements consist of a foundation and a surface course; either constructed separately as with sheet asphalt or brick on a rigid or flexible base or constructed simultaneously as a concrete pavement.

For any type of pavement to give continued service it is essential that there exist a well drained sub-soil, a stable foundation and a wear resisting surface. In years past many such wonderful pavements of various types and designs were constructed, returning to the taxpayers every dollar's worth of investment in real service. But as time progresses and traffic increases, the surface of these pavements wear down, some evenly and some so unevenly that they become unfit for travel. Whence, complying with a popular demand for a new, smooth pavement, the authorities proceed to replace them. In many of these cases, all that is needed is a renewal of the surface course. The foundation may be in perfect condition, having received the compaction of years of traffic, which is so much more effective than can be secured in any other way.

Inasmuch as economy is the aim of good engineering, it behooves the one in charge to make all necessary investigations to determine the adequacy of the existing foundation, to the end that it may be preserved. If this can be accomplished, a saving of approximately $1.20 per square yard will be made.

When all information is at hand, the design of the surface for each particular job can then be determined on its merits and becomes purely a matter of the engineer's judgment.

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In Richmond we have effected a considerable saving by using bituminous surface over old worn pavements. This resurface work has come under two heads; that which is done without removing the old pavement surface and that which does remove it.

In our experience we have resurfaced with the following types:

Bituminous macadam over old gravel and old macadam pavements.

Sheet asphalt over old gravel and old macadam pavements.

Rock asphalt over old macadam and old brick pavements.

Preparation of the Surface

Where a bituminous top is to be laid over an old gravel or macadam street from which a portion of the old surfacing is to be removed, great care is exercised in making the excavation. The scarifier teeth are adjusted so that only part of the required depth is loosened at a time, leaving the surface firm and compact after the removal of the loosened material.

Where the depth of the gutter may be reduced, the present surface is first cleaned and when using sheet or rock asphalt for the surfacing, the pavement is brought to profile by the use of black base. When using bituminous macadam for the surfacing, the small irregularities can be adjusted by an excess of stone.

Soft places in the foundation and service cuts are reinforced by a six-inch Portland cement concrete or black base slab.

Rock asphalt is a material which is well adapted for resurface work. It has been used successfully in many cities in this state and others. It is a material comparatively simple to handle and requires a minimum of contractor's equipment.

In the resurfacing of old macadam, it is essential that the rough aggregate in the old surface be exposed by thorough sweeping. This provides a bond for the surfacing asphalt. If a firm, clean surface cannot be obtained, it is often advisable to excavate and replace with a layer of new stone 2½ inches in thickness, constructed and water-bound as in macadam base construction.

Guide strips are laid four to five feet apart between which the asphalt is raked and smoothed. The strips are of such depth as to provide for one-third compaction.

Care is exercised in thoroughly raking the material and leaving the top of the finished surface free of all lumps.

Rolling is done in the customary way with a ten-ton roller, until the surface is smooth and compact.

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In resurfacing over brick or concrete the surface is thoroughly washed and swept clean, then brought to profile with black base, after which the cleansed surface is uniformly painted with asphaltic cement by means of an ordinary whitewash spray.

If desired, the rock asphalt may be feather edged 5 to 6 feet from the gutter and also at the car tracks, if any exist.

One inch thickness has proven suitable for this surfacing.

Sheet asphalt has been and is now being used quite extensively as a resurfacing over old pavements of all types.

This material is laid in resurface work similar to constructing it on a prepared foundation.

Sheet asphalt cannot be successfully feather edged. It requires a shoulder.

Bituminous macadam has been used successfully over old gravel and macadam pavements and is doing a large service on the state roads.

The same methods of construction are followed in resurfacing as in new construction.

There are other types of resurfacing materials which have given service in many cities of the country. I have only mentioned those we have used in Richmond.

GREATER SAFETY AT RAILROAD HIGHWAY CROSSINGS

By Chas. E. Hill,
General Safety Agent, New York Central Lines,
New York City.

In discussing safety regulations at railroad highway crossings we must do so from a broad standpoint, having in mind not only the problems with which we are confronted today but we must also take into consideration the conditions we may reasonably expect to exist in the future. This subject is a vital one and is of tremendous importance in any plan we may adopt in our efforts to reduce accidents at railroad highway crossings.

During the seven-year period from 1917 to 1923, inclusive, as a result of crossing accidents in the United States there was a yearly average of 1,882 deaths and 5,100 injuries, and during 1924 there were 2,149 persons killed and 6,525 injured in this manner, an average of 24 casualties per day, as

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compared with 9 per day 12 years ago, an increase of 167 per cent, which is not in harmony with the increase in the population of our country during the same period, amounting to only 15 per cent.

We must not overlook the fact that casualties resulting from crossing accidents are not confined to the user of the highway, for in 1922 there were 27 derailments of trains due to accidents of this character, causing death and injury to 138 railroad employees and passengers, in addition to a tremendous loss of property.

The Physical Situation

On December 31, 1924, we had in the United States 242,807 crossings at grade. In seeking a remedy we must do so upon the theory that the future holds no panacea insofar as the physical situation is concerned, for it has already become an acknowledged fact that a solution of this problem, through crossing elimination, is unthinkable by reason of the prohibitive expense, conservatively estimated at 20 billion dollars, and the time required to perform such a stupendous task. Twenty billion dollars is greater than the preliminary estimated value of all railroad property as made by the Interstate Commerce Commission. It is almost equal to the combined resources of the national banks of our country. Certainly, no further argument should be necessary to show the utter inability of the railroads and the municipalities to shoulder such a fiancial burden.

A progressive plan of crossing elimination should be carried on, and so far as the New York Central Lines are concerned this policy is being pursued, this feature being taken into consideration in the preparation of the annual budget.

A gradual process of crossing elimination has been and still is being carried on by the railroads, but they have been seriously handicapped by the addition of many more new crossings. For example, in 1923 (which is the latest year for which statistics are available) the railroads of the country eliminated 972 crossings at a cost of about 100 million dollars, but during the same period 3,065 new crossings were constructed under conditions over which the railroads had no control. Even should crossing elimination be conducted on a more general scale we could not hope for a solution of the problem by this means for many generations to come. We must, therefore, accept the situation and meet the conditions as they exist.

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The Motor Vehicle

We have in the United States, in round numbers, twenty million motor vehicles. The motor vehicle is specifically concerned since it will be involved in 90 per cent of our crossing accidents this year. The number of automobiles will continue to increase, for it is estimated that in seven years there will be not only one car for every six persons as exist today, but the ratio will be increased to one car for every four persons; in fact, by that time we will have 33 million motor vehicles, a number sufficient to supply one vehicle to each individual that is old enough to reach the steering wheel.

The automobile today is an absolute necessity in the conduct of the business of this country and progress will demand not only its continued use but a greater extension of its services. It is by reason of this situation that it becomes imperative that we, in our attempt to provide a remedy, not only endeavor to take care of our present day needs but of the future as well, and this will include a regulation of the use of the motor vehicle so that it will serve the purposes for which it was intended.

Analysis of Accidents

In making this analysis we find 70 per cent of our crossing accidents occur in daylight, 63 per cent at crossings where there is no obstruction to view and a large majority at crossings with which the driver is familiar—in the community where he resides—which clearly indicates that he is so familiar with the situation he feels he is immune to danger and drives heedlessly on the tracks without using any care whatsoever; or he sees the train approaching and increases his speed in an effort to beat it over the crossing. It is, also, of interest to know that one out of every 5 crossing accidents results from the automobile running into the side of the train. Some drivers failing to beat the train over the crossing attempt to "butt" it off the track.

A large percentage of drivers are wholly incompetent, due to either mental or physical defects. Mental, due to inability to read or understand the English language; physical, due to impaired vision or hearing, immature age and enfeebled condition, due to old age. A large number of these accidents can be charged to intoxicated drivers. It is certainly indicative of something lacking in our laws when men of the type described as mentally and physically defective are permitted to drive automobiles. But, it is obviously grossly neglectful to permit them to be operated by drunken drivers.

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A judge in one of our large cities some months ago remarked from the bench that an automobile in the hands of an intoxicated driver is far more dangerous than a loaded revolver in the hands of a maniac on a crowded street.

Contrast the comparative qualifications of the driver of an automobile and the driver of a locomotive. The former, as a rule, needs no qualification other than his ability to possess a car. He is not only unfamiliar with its operation but is lacking in a knowledge of our laws governing its use on the highways. In many instances his responsibilities are such that he is weakened in his regard for the rights of others. Whereas, the locomotive engineer has earned his right to a seat in the cab of his engine by virtue of many years of training. He is not only familiar with its mechanism and operation but also with the rules governing its movement over the road. His responsibilities are a part of his makeup. He sits in his cab not only with these qualifications but with a steady hand, a clear head, a brain that is nowise affected by anything he may have drank and with a keenness which is so alert that he is, in fact, a part of the locomotive being operated under his guidance.

While 25 per cent of the drivers do not use the care requisite to safety, yet, only about 5 per cent are grossly neglectful, using no care whatsoever. Thus, we find that only a small percentage of the drivers are careless, yet, if this were not true it would only be a few years until our country would be depopulated, for during last year, as a result of automobile accidents in our streets and highways, including those occurring at railroad crossings, there were 19,000 persons killed and 450,000 injured, an increase of 700 per cent in 12 years. The percentage of careless drivers is small, yet it represents a large army of 1,000,000 reckless demons flitting about the country having no regard for their own safety or the safety of their fellow men.

The reckless motorist is regarded as the greatest menace we have today in the safe operation of passenger trains, for he is, indeed, a potential train wrecker.

While crossing accidents during the past 12 years have increased 167 per cent and automobile accidents of all kinds have increased 700 per cent it is interesting to know that during the same period passenger fatalities on the American railroads have decreased 59 per cent. While the railroads have in certain instances reduced the speed of some of the best passenger trains as a greater assurance of safety, the speed of the automobile has increased. The act of foolhardiness has been changed from "Blowing out the Gas" to "Stepping on the Gas."

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In showing the relative comparison of safety in travel by automobile and by train your attention is called to the fact that during 1924, which is the latest year for which we have available statistics, there were 19,000 persons killed by motor vehicles, of which number 6,650 were passengers in the machine. There were, also, 450,000 persons injured, of which number 157,500 were passengers in the machine. During the same year there were 41 passengers killed and 2,260 injured in the United States as the result of passenger train accidents. In other words, confining ourselves to casualties to persons riding in the motor vehicle and to casualties to passengers resulting from train accidents, we find the motor vehicle deaths outnumber those to passengers on trains 160 to 1 and the injuries 70 to 1.

As regards public safety, the public is responding to our appeals for co-operation. We are receiving the support of national, state, county and municipal officials. We are receiving aid from those organizations having to do with the manufacture and sale of automobiles. Many civic bodies are contributing nobly to this work and the churches and schools are lending most effective support. But this co-operation needs developing. If our contact with automobile drivers was as close as it is with our employees and the response toward co-operation was proportionate we would reduce crossing accidents 50 per cent within a year, and eventually would bring them down to an infinitesimal number.

It seems that tragedies of an appalling nature are necessary to awaken the conscience of America. The accident frequency in this country has reached such gigantic proportions as to demand national recognition and, due to this fact, the Hon. Herbert Hoover, Secretary of Commerce, called a National Safety Conference, at Washington, last December. This conference devoted two days to a careful study, discussion and analysis of the accident problem. Every agency having to do with the causation and prevention of accidents participated in the program. President Coolidge in addressing this conference said: "If the death and disaster that fall upon the innocent people during the year and throughout the country as a whole were concentrated into one calamity we would shudder at such a tremendous catastrophe," and in speaking further he said: "The yearly toll of accidents has reached an appalling total, the evil is so widespread as to be of national concern."

The Remedy

What is the remedy? This is a joint responsibility between the railroads and the public. The railroads have a duty

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to perform. We must not lessen our efforts toward increased efficiency in the maintenance and protection of highway crossings and in the manner of train operation as it applies to accidents of this character. Our every act in the discharge of our duties in this regard must carry a sincerity of purpose of such positive character as will convince the public of our real devotion to a most worthy cause.

The remedy lies largely in a constructive campaign of education. We must find some means to curb the reckless motorist and at the same time make driving safer for the great majority of motorists who are careful.

As an aid to this plan I would suggest the public can render effective service by carrying out the following suggestions:

1st. The prevention of the building of unnecessary highways across railroad tracks.

2d. The elimination of crossings through the re-routing of highways wherever possible.

3d. The elimination of obstructions to view on the highway within 500 feet of the crossing.

4th. Require every owner, driver and insurance carrier of every automobile involved in an accident causing personal injury to report full details thereof to designated state officials.

5th. The enactment of stringent laws requiring a proper standard of qualifications, making it impossible for motor cars to be operated by those who are unable to meet the required mental and physical tests.

My belief in the justice of our cause, coupled with my deep-seated faith in the fairness of the American people, gives me hope for the future. I believe the signs of the times point to a rule of law laying down a standard of competency to be met before licenses to drive motor vehicles will be issued. When this is done we will weed out a large army of present-day drivers who, by reason of defective vision, cannot see the train, much less the crossing; who, by reason of impaired hearing, cannot hear the roar of a cannon, much less the locomotive whistle; who, by reason of mental defects, cannot understand the operation of the car, much less the rules governing its use on the highway. We will weed out the old and decrepit who have retired from every form of activity excepting the God-given right to drive the family car; and, lastly but not least, we will remove from the steering wheel those whose right to operate a car is in fact a travesty on justice—the drunken driver whose acts are materially augmenting our casualty record at this time.

Through a greater spirit of co-operation there were 119 fewer crossing fatalities in the United States in 1924 than in

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1923. It is our hope that all organizations and agencies, civic, political and otherwise, that are in any manner concerned in the conservation of life and limb and whose aid is so essential in the success of this movement will unite in a common enterprise and that as a result our co-operation will become more extensive, so that it will assume a force of such magnitude and power as will serve to wipe out this needless slaughter of human life.

SURVEYS AND PLANS FOR COUNTY ROADS

By W. W. Southard,
Marion County Surveyor.

There has been a great improvement during the last ten years in the method of making road surveys and in the care taken in the preparation of plans for road improvements. Formerly it was almost universal custom for surveyors to run levels down the center of the proposed road and merely plat a profile showing the difference in elevation at one hundred foot stations. A new grade line was shown which gave the cuts and fills in the center of the road but there was no way to determine the amount of earth to be excavated at the sides. Consequently the surveyor's estimate was a guess, and similarly the contract in making his bid could only approximate the amount of earth to be moved.

The entrance of the State Highway Commission into the field of road construction has given the surveyors of the state an example to follow in the method of making surveys and the preparation of plans. The Bureau of Public Roads of the U. S. Department of Agriculture has laid down very exact and definite requirements which must be met by all states on Federal Aid Roads. In turn the Indiana Highway Commission has made rulings covering the plans to be submitted to them by the counties when asking state approval of plans and specifications. This, together with the desire of most surveyors to prepare plans as nearly approaching the perfection of those of the State Highway Commission as practical, has resulted in the improvement mentioned above.

I will try to outline briefly the methods to be followed in surveys of the different types of roads in this state.

In the central and northern part of the state most of the roads follow section or half-section lines. In the southern part

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of the state, on account of the rough and hilly nature of the topography, it was necessary in most cases to locate the early roads to follow the water courses and wind around the hills, "meandering" roads I will call them.

In the re-survey of roads of the first type mentioned the section and half-section corners should first be located. In case any of these have been removed the surveyor should make a re-survey of the section and set the corner, as it is essential that the permanent improvement should be correctly located so that our successors will not make wrong assumptions on land surveys. These section and half-section corners should be referenced so that if taken out during grading and construction, permanent markers can be set in the surface of the finished road.

After the corners are located the center line of the road should be run with an engineer's transit and each station marked, either by means of an offset stake set along the side of the road at some definite offset, or by means of marks in the center of the road. I prefer the latter method and use for this purpose a two-inch oval head spear point hinge nail with a small piece of red calico two inches square. We find that these center line markers will stay for a sufficient length of time to permit us to get about two or three miles of center line located, then come back and run levels over the points.

In running levels it is always desirable to use sea level datum. If you have no elevations based on this datum such can usually be secured by writing to the division engineer of any railroad running through the locality. Where sea level datum cannot be secured it is permissible to assume a starting elevation. The elevation should be secured at all center line points and abrupt breaks in ground level, with elevation of sufficient points on each side of the center line to give an accurate cross-section of the road at that point. The flow line or channel elevation at all pipe culverts and other structures should be secured, also the floor of bridges and slab culverts and the top of the crown on all arch structures.

It is well also to ascertain the condition of all culverts and structures and note same in the field book. Look through pipes and see if they are functioning properly or if they are worth leaving in place and make recommendation on each. Sketch all structures and supply all important dimensions so that plans can be prepared for widening or repairing if the condition warrants.

Bench marks should be set at intervals not greater than one-fourth mile and upon completion of the profile check levels should be run back over these benches. This will locate errors in rod readings or computations during the survey and save

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trouble when construction is begun. You will find it of great assistance later if you make recommendations in the field book regarding the amount of cutting or filling advisable at various points and also concerning drainage features that may be noticed during the survey.

On the winding or meandering roads the procedure is as outlined above, except that the location of center line is not limited. These old roads have been located on vague descriptions which in most cases are impossible to relocate and the surveyor is at liberty to pick his new location to fit modern requirements. He can vary from the original road where desirable to make a better location and should exercise his judgment in such matters as the survey proceeds. The new center line should be tied into the nearest section or half-section corner and the angle between the center line and section lines read. Reference in all deflection points, measure the external or distance from point of intersection of tangents to the location desired for center line on curves, and from the table of "Functions of a One-degree Curve" in the Engineer's Hand Book ascertain the degree of curve and the tangent lengths. The curve can then be run in and cross-sections taken from points on the new center line.

In preparing the report of viewers and engineer a corrected description should be used so that the road as relocated can be put on future maps and plat books.

In drafting the plans it is advisable to use the plan and profile sheets recommended by the Bureau of Public Roads, either Plate I or Plate II. The contractor for county printing can secure these for you and if paper is used the cost is not high. The plan should show all physical features on the existing road, such as fence lines, pole lines, railroad or interurban tracks, buildings near enough to the road to be affected by the improvement, and all structures encountered during the survey.

The profile should be plotted at a scale of 100 feet to the inch horizontal and 10 feet to the inch vertical, the grade line laid and vertical curves supplied at all pronounced changes in grade. Station numbers, elevations on profile and elevations on new grade with the amount of cut or fill should be shown below the profile.

The cross-sections should be platted on cross-section paper or on Plate II of the Bureau of Public Roads standard with a scale of five feet to the inch. The area of cut and of fill should be measured separately, preferably by use of a planimeter, and entered on the sheet at the section measured. These areas should also be entered on a tabulation sheet, the areas of adjoining sctions averaged and the volume of earth wo

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computed. The plans department of the State Highway Commission has a table of earthwork volumes which is valuable in that it saves much labor in computing these volumes.

With the amount of earthwork determined you will know whether it is desirable to leave the grade line as located or to raise or lower same for more economical construction. After the earthwork quantities are finally determined they should be entered on the profile between balance points and the engineer is ready to prepare his cost estimate and write the specifications.

It will be readily understood that in a paper of this sort no attempt can be made to go far into the details of surveys, preparation of plans or specifications. I have endeavored merely to sketch an outline of the procedure in the field and office. Each surveyor will have to work out his own details in accordance with local conditions and the type of improvement. Too much care cannot be taken, however, in any of the steps and the carefulness and accuracy of the surveyor will be reflected in the completeness and therefore usefulness of the plans as prepared. The cost estimate should be carefully prepared so that it will be useful to guide the contractor in preparing his proposal. Good plans and sensible estimates attract reputable contractors and result in satisfactory workmanship, thereby giving the public a proper return for the investment.

TEST ROAD IN ST. JOSEPH COUNTY

By A. C. Mangus,
St. Joseph County Highway Superintendent.

No highway improvement can be considered as permanent—forever enduring. The period of useful life of any highway improvement is limited. The time will come when the pavement must be reconstructed. This period of useful life may be longer, under like conditions, with one type of construction than with another. In any case the period of useful life is lengthened by careful attention to the maintenance of the improvement. By proper maintenance the day of reconstruction may be delayed and the period of useful life lengthened, permitting us to have the use of the pavement at a lesser cost per year by distributing the first cost over a greater number of years. However, the time will come when the

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yearly cost of maintenance will be as great as the yearly cost of the added investment for reconstructing the improvement—then reconstruction is advisable.

This is true of the Lincoln Highway west of South Bend, a section of pavement in the neighborhood of 13 miles in length constructed in 1915-16. The three miles adjacent to the city were completed in December, 1916, during freezing weather.

Traffic from Chicago to Toledo, Cleveland and Buffalo pass over this section of the Lincoln Highway. Traffic from Detroit, Lansing and Jackson enter South Bend over the Ear Trail and there converges with west-bound Lincoln Highway traffic, all passing over this particular section. This traffic separates again at Rolling Prairie, a part taking the Dunes Highway through Michigan City to Chicago, the remainder following the old route through Laporte and Valparaiso. This is evidence in itself that this particular section carries the greatest amount of traffic of any section of the Lincoln Highway between Chicago and Toledo.

In the spring and summer of 1925 this section began to deteriorate in alarming proportions. Steel in the expansion joints began to raise out of its moorings to such an extent that it became a menace to traffic, such that in a great many instances it was necessary to pull them out with trucks. This caused a spalling of the concrete back from the joint six inches to three feet. Especially did this occur in that section that was installed during adverse weather conditions of the winter of 1916. During the summer a force of from six to eight men were patching practically half of the time. It became apparent to the board of commissioners and myself that the time had come when the cost of maintenance was greater than the added investment for reconstruction would be.

What material to use, what sort of top to put on this old pavement became a mooted question. Material men naturally recommended a top that would require their material. Contractors urged that material that would require the use of their particular equipment in installing the pavement. This diversity of opinions and the fact that the state was building a concrete road on the Division Highway from South Bend to Rolling Prairie, thereby shortening the distance between these two points by two miles, and that the building of that road would have a tendency to divert the heavy traffic from the Lincoln Highway to this new route, influenced us in building a test road as the logical way out of this difficulty.

Accordingly, the county engineer was instructed by the board of commissioners to prepare plans and specifications for six different types of road: concrete, penetration macadam,

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sheet asphalt, asphaltic concrete, rock asphalt and emulsified asphalt. The contracts were let in August and the last section was completed in September, 1925.

The first section of five inches of reinforced concrete was built by Reed and Sons of Mishawaka at a cost of $2,150.

The second section was of penetration macadam rolled to three inches, built by the Highway Improvement Co., of South Bend, at a cost of $1,100.

The third section is sheet asphalt rolled to a thickness of three inches, built by the Williston Construction Company, at a cost of $1,430.

The fifth section is rock asphalt rolled to two inches, built by the Highway Improvement Company at a cost of $1,400.

The sixth section of emulsified asphalt rolled to one inch was built by the Emulsified Asphalt Company of Indianapolis, at a cost of $1,150.

In mentioning cost, we refer to the contract price, each section being let by contract. The several sections were each 500 feet in length. In choosing a location, we took a section of highway that was devoid of cross and side roads, thus compelling all traffic to traverse each and every section.

What the ultimate outcome will be, we are unable to say. Time alone will enable us to determine what type of reconstruction will be the best and most practical for future traffic on this particular road.

THE CITY'S SHARE IN OUR TRAFFIC PROBLEMS

By W. P. Cottingham,
City Engineer, Gary, Ind.

From New York to Los Angeles—from Duluth to Jacksonville—the people are clamoring for a solution to the traffic problem, and none of them are willing to be prevented from building up congested high value districts. Buffalo, Detroit, Toledo, Cleveland, Chicago, St. Louis, New Orleans, Indianapolis—all our great commercial cities are paying the price for congestion. Many are hopefully watching the experience of Washington, D. C., where precedent was recently upset and the traffic problem placed in the hands of an engineer. A great many accomplishments have been recorded in the past year, but the weak spot was found to be the lack of oppor-

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tunity to enforce the traffic rules laid down. The engineer brought forth many useful ideas, but met with considerable difficulty in enforcing them. This might turn us back to the question, "Do the people—who are the city—want traffic regulation?" Of course they want it for the other fellow, but until they decide they need it for themselves it is a job for the policemen to force them into it.

The American Engineering Council has announced the organization of a nation-wide movement among engineers to solve the growing traffic problem. A general committee is to serve as a clearing house of ideas between the engineering societies and the National Conference on Street and Highway Safety. Their announcement says: "In every community in the United States the traffic problem is acute in some form. The country is beginning to realize that this problem is essentially of an engineering character. This is because, in most places, the local police have reached the limit of accomplishment and still the problem continues to grow with increasing speed and seriousness. Under these circumstances, it behooves the engineering profession to undertake to meet its responsibility in the matter."

Congestion is invariably the cause of our traffic problems. If there was no congestion on our streets we usually believe there would be no problem; but the fatal traffic accident does not occur in congested traffic as often as in the clearway where speeding occurs. Reckless driving must be curbed through the exercise of police power but congestion must be remedied through the application of engineering knowledge and common sense.

Improperly controlled traffic in the United States costs $2,000,000,000 a year or $20 a year for each man, woman and child in the nation, according to estimates made in official reports. That is the price the country is estimated to pay in loss of life, accidents, loss of time through congestion, depreciated real estate values and in other ways for the lack of properly developed traffic facilities and their control. This estimate, which is four times the waste caused by fire losses annually, is based on data gathered by the committee on metropolitan facilities of the national conference on street and highway safety.

What does congestion cost the public? A recent study in Chicago develops the fact, quite logically, that time valued at $26,250,000 could be saved annually by the citizens of the city if one-half hour could be gained in the time spent in transportation. In this estimate it is considered fair to count the time of various classes of traffic as worth so much per hour, and to allow a reasonable length of time to make

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given trip. What time is consumed in making the trip over and above the reasonable or expected running time may be valued at fifty cents per hour for pedestrians and passengers, $1.25 for horse drawn vehicles, $2.50 for automobiles or motor trucks, and $5.00 per hour for street cars. A motor car with driver and two passengers will gain time valued at $1.75 per day if a reduction of fifteen minutes each way is made in a daily journey to the city. In 300 days the value of time saved the car and occupants is $525.00. At this rate 50,000 cars entering and leaving the city daily will be saved time valued at twenty-six and one-quarter million dollars ($26,250,000) yearly.

It was considered remarkable a few years ago that St. Louis could approve a bond issue amounting to eighty-seven million dollars ($87,000,000) for developing their major street plan, yet in view of figures like those given for Chicago it would seem a most logical procedure. Through the development of the major street plan in St. Louis the traffic problem is being relieved—adequate street widths, to accommodate the present and future traffic, are being secured. The street improvements are being designed to carry the traffic expected both in respect to number of vehicles and weight of loads. They are building safety into the streets in all ways known to them and are giving to the citizens of St. Louis the benefit of their sincere attempt to apply engineering knowledge to the solution of the traffic problem.

Some Attempted Solutions

Two present conditions are set down in this discussion as permanent—as known quantities. Automobile speed is not going to be cut down; rather it is likely to increase. And the number of automobiles is going to keep climbing; the saturation point is still far off. There is no use fighting these conditions. They must be accepted, and the building of safety into streets and roads must be planned accordingly.

In cities like Chicago it will require the separation of heavy and light traffic, pedestrian traffic and traction and railroad lines; the creation of through routes protected by traffic signals; subways under streets or bridges over streets at schools or other important pedestrian crossings; smooth paving of streets; widening and straightening of streets; placement of safety islands at dangerous crossings; removal of obstructions from the streets; and a traffic signal to give the pedestrian an equal chance with the automobile to cross in safety.

Los Angeles has proceeded during the past year to put

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some of these practices to the test and in addition to reducing its automobile fatalities in 1925 they have speeded up traffic 60% and trolley traffic 30%. If time is worth anything in California the saving should be in the millions. At any rate, lives are worth saving and this report indicates a justifiable claim for the saving of 29 lives in the year despite an increase of 15% in the number of autos operated.

In accomplishing this the metropolitan traffic control system has been operated to regulate pedestrian as well as vehicular traffic. Stern traffic and parking rules have been enforced. Tunnels have been built under busy boulevards for the children going to and from schools. Jay walkers and pedestrians going against traffic are arrested. Passenger safety zones protected by traffic buttons give the necessary protection to street car traffic.

Detroit claims the distinction of having the densest traffic points in the country, a condition formerly found in New York. An official report shows that traffic in Detroit at Grand River and Grand boulevard west is in excess of what it was at the last count made at Forty-second St. and Fifth Ave., New York. Traffic at Jefferson Ave. east and St. Antoine St. exceeds the traffic at the famous New York intersection by 18 per cent. The 15 heaviest traffic streets in Detroit carry at the center 4 per cent more than the 15 heaviest traffic streets in New York.

Detroit is undertaking the solution of this problem through the establishment of a complete system of superhighways encircling the city and providing optional routes into, through and around the congested areas. In general the layout provides for rights-of-way 204 feet in width, improved with two 40-foot pavements separated by a car track space. On the two paved areas traffic lanes are established to segregate the fast through traffic from the slower heavy or local traffic. Intersecting streets and approaches to the car tracks will pass under the lanes of fast traffic and regulated speeding will be encouraged. The development has reached a stage in Woodward Avenue that is attracting the attention of traffic officials and city planners from many communities.

Arthur S. Tuttle, Chief Engineer of the Board of Estimate and Apportionment of the City of New Work, speaking on City Planning as a Permanent Solution of the Traffic Problem, is quoted as follows:

". . . It was not until about 1903 that the inadequacy of our present streets began to be realized, and since this date there has been a continuous progressive movement in the direction of improving conditions at points of congestion.

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. . . With a view of ascertaining the sense of the community and more particularly the views of the various organizations which have made the problem one of great concern, a public hearing was given by committee in New York a short time ago for the purpose of collating all of the suggestions which might be offered as an aid in its investigation, at which time, however, practically no suggestions of value which could be construed as strictly novel were offered, although most of those which have heretofore been under consideration were placed in evidence, these comprising the following:

1. The systematic control of street traffic, both vehicular and pedestrian, in which connection an effort should be made to bring about uniformity in traffic signs and signals throughout the country, with sufficient variation in control to meet the requirements of local situations.
2. The improvement of existing streets through the removal of obstructions, the laying of smooth pavements, the widening of roadways where practicable without undue encroachment upon the sidewalks, and the provision of easy curves at the intersections.
3. The introduction of by-passes to enable through traffic to avoid congested centers.
4. The limitation of the dimensions and weight of different types of vehicles.
5. The fixing of roadway widths to conform with the types of vehicles which they are likely to be called upon to accommodate.
6. The separation of grades at street intersections at points where this can be effected without undue property damage.
7. The construction of elevated express streets along the waterfront or where they can be introduced without undue deprivation of light and air or interference with surface traffic.
8. The provision of adequate parking accommodation for automobiles in or near the congested business and commercial centers, this being accomplished either by setting aside public areas for this purpose or through the construction, either municipally or privately, of parking garages.
9. The placing of the burden of providing parking and loading spaces at least in part upon the property owners.
10. The widening of existing streets, where practicable, or accomplishing a similar result by the introduction of sidewalk arcades with a corresponding widening of the roadway.
11. The cutting through of new arterial streets where additional facilities can be obtained by no other method.

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12. The control of density of traffic by imposing additional restrictions on height of buildings.

13. Lowering the peak of vehicular traffic by compulsory night trucking.

14. The substitution, where practicable, of buses for surface railroads, and the removal of abandoned surface tracks.

15. The construction of underground rail facilities for the delivery of store freight.

16. The provision of undercrossings for pedestrians at the busy traffic points, preferably in connection with the operation of underground rapid transit systems.

17. The setting up of more liberal standards for the width of both local and arterial streets in the planning of new territory, or the assignment of a greater proportion of the city area to street purposes.

18. The acquisition of court yard areas during early stages of development which can be thrown into the street system when and as required."

Many of the suggestions offered in this list have been applied to the traffic problems of other communities and many of them are not at all applicable to your local problem or to the traffic problem of Gary. In studying our local problems we find that we must work out our own salvation—and it is usually undertaken with fear and trembling. When we can find a similar problem satisfactorily solved in some other community we gratefully accept it as a guide for our endeavors. When we find that some other community has solved one of their problems in a similar manner to our solution we feel that they must surely be a wide awake and exceedingly progressive group.

President Elliott, last evening, expressed the hope that the state road system would be so developed that it would give state-wide access to all the state parks. To accomplish an entrance to the newly acquired park in the Dunes will require some solution to a traffic problem that at present is quite effective as a barrier to the Dunes on a good day in summer. The Dunes Highway is so overloaded with traffic on Sundays and holidays that drivers have spent from four to five hours traveling on concrete pavement the distance of 25 miles from Michigan City to Gary.

The Chicago City Council has effected the creation of a Street Traffic Commission to make an analysis of traffic problems for a year and then to formulate a comprehensive traffic plan and uniform traffic code for the Chicago Metropolitan area. The commission is to be made up of aldermen, city officials and the street traffic committee of the Chicago Asso-

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ciation of Commerce which proposes to furnish $50,000 for the first year's survey operations.

Already they have developed some rather startling data in reference to truck traffic. On the highways leading into Chicago the truck traffic is not 25% to 40% as the average driver supposes but less than 7% as shown by traffic count. The maximum truck traffic is on Indianapolis Avenue where in the count of 12,635 motor vehicles, 782 or 6.2% were trucks. The average on all roads is probably about 4%. On a study of truck traffic it was found that about 96½% of total truck mileage is on city streets.

The fact that Gary is in the district being studied by the Chicago Regional Planning Conference and is co-operating in this study is offered as an explanation for the use of so many examples from Chicago.

When we find, as we found last summer, that approximately 1,000 cars per hour were passing through our city with no desire to stop, we set about making it easier for them and safer for our citizens. We opened up and widened a route that became available as a by-pass to separate this through traffic from our local traffic.

When we found that our main down town street was becoming inadequate because of rough pavement, poor car track construction, and unlimited parking, we remedied the situation by paving the entire width with smooth pavement, limiting parking to one hour, removed the raised cross walks, increased the radius at intersections and have as a final step removed the center poles that have been supporting the trolley lines on brackets. This final step has accomplished the mental effect of increasing the width of the pavement about six feet.

There are many other items that enter into the traffic problem. Congestion of traffic at railway grade crossings on busy streets may be eliminated through grade separation and many of our Indiana cities are proceeding to remove this obstruction both as an obstruction and as a hazard.

The installation of traffic signals, if given the proper preliminary study, will certainly assist in regulating and directing traffic. It has been our experience in Gary that our signals are best adopted to serve the needs of the community when they are of the same type as in use in Chicago. This but emphasizes the need for uniformity in signals.

In some cities one-way traffic on some streets solves the problem but we have not found this true in Gary. Chief Collins of Chicago stated recently at the American Road Builders' Association meeting that Chicago could not operate on one-way traffic streets.

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Gary tried out a restriction against left turns at several busy intersections and received such protest from the business men in all directions from the several intersections that the rule was abolished.

TRAFFIC OBSTACLES

By Howard R. Olson,
Engineer, Chicago Regional Planning Association

There is nothing complicated or involved in the regional planning idea. It is merely a simple answer to a difficult problem that arises whenever similar or related work extends across political boundary lines. The condition that gave rise to the Chicago Regional Planning Association is the same that caused state highway commissions to be formed throughout our country, namely, a common problem too big for small political units, separated as they are, to handle effectively. The result desired was also the same: a co-ordinating influence to bring about unity in local plans and work with greater vision for future needs. The principle underlying the Chicago Regional Planning Association is a departure from that usually followed in metropolitan planning. It recognizes all officials whose specified duties are related to the work involved. It also includes public spirited citizens whose special knowledge or interest will be of value. These men are made consultants and directors of the planning and what special staff is required, work under their policies. The final result is that all phases of the plan receive immediate public support and are assured of realization.

Although the Chicago Regional Planning Association is concerned with all problems bearing upon community development, such as water supply, sanitation, rail, water and air transportation, parks and forest preserves and others, the most important and urgent is highway transportation. The common problem confronting the highway authorities in the many counties and towns grouped around the lower end of Lake Michigan can be divided into two parts: one, transforming their old horse-and-buggy age roads and streets into more efficient and safe carriers of motor vehicle traffic; and, two, planning every new road for modern automobile traffic with extra width for future widening when traffic conditions warrant.

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The problem, of course, is at present more intense near the cities of Chicago, Hammond and Gary and likewise near all large populated centers. It does not differ, however, from that which exists in every town in Indiana, Illinois, Ohio or any other state. Motor transportation is just in its beginning. What is now true around our larger cities will soon be true in our smaller towns. The disease that blights the highways around our larger towns is now, farther out in the country, in its first stages. But, if the highway officials will prescribe the right kind of treatment now, doctor bills and surgical operations on their respective highways will not be half as expensive as later.

The term traffic obstacle in general usage is not limited in its meaning or very definite. In this discussion we will say that any regulation, any regulatory device or any physical feature existing in or along a street or highway that prevents or reduces the economical, free or safe operation of motor vehicles is a traffic obstacle.

Why should traffic obstacles be discussed at a meeting of Indiana highway officials and engineers? The most important reason is that decreasing the cost of operating the hundreds of thousands of Indiana motor cars is just as important as decreasing the cost of building and maintaining the highways over which they must travel. In order that we may gain a rough idea of the importance of operating costs in dollars and cents so that due regard may be given to improvements which will reduce those costs, let us make a few computations.

In 1925, Indiana registered over 650,000 motor vehicles. Assume that each traveled 5,000 miles during the year and the cost of operation for one mile was 10 cents per vehicle—an amount found by investigators of the Engineering Experiment Station of Iowa State College to be average. Multiply the three figures together and the total operating cost to automobile owners of Indiana figures out to be over $325,000,000. Now let us suppose that if, throughout the state, all chuck holes and worn out pavements that break springs and shorten the life of an automobile, sharp jogs and many other traffic obstacles were repaired or removed the saving in operating costs would amount to one-tenth of a cent for each mile of travel. The total saving effected would total over $3,250,000.

It is, without question, important to construct and maintain high grade surfaces on our main thoroughfares. One of the objects of this paper is to briefly describe the methods followed by the highway authorities of the Chicago region to raise the quality of their existing paved highways and lower the operating costs.

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Traffice Obstacle Surveys

The Committee on Highways of the Regional Planning Association includes highway officials of the federal government and states, counties and cities in the region. To that group of men, who direct the construction of many million dollars worth of roads each year, removing traffic obstacles is a most important service to the people of the region. It was for that reason that they inaugurated a series of traffic obstacle surveys to be made on the main traveled highways leading out of the city of Chicago to be followed by a campaign pointing out the defects and urging their removal.

Each survey is started at the loop district of Chicago and is carried outward, through the many suburban towns and into the country for a distance of at least 50 miles. From beginning to end roadway widths are recorded and logged along with bottle necks, sharp jogs and turns, rough pavements, unpaved car tracks, railroad grade crossings, narrow bridges and subways, dangerous sections of the road and any other conditions which slow down or stop traffic or increase the cost of traveling over it. From the notes taken the observer makes sketches of the more important obstacles and shows or describes means of improving each. Strip maps are also drawn showing diagrammatically the variation in widths of the roadway over them. The survey is then reviewed by the members of the committee, many of whom are familiar with local conditions along various parts of the route, and the procedure outlined to bring about the improvement of each obstacle. Meetings are arranged with the local authorities having jurisdiction over each section at which ways and means for effecting the work are decided upon. In every instance the many local officials, good road committees, commercial clubs and newspapers realize the value of the work and give their fullest cooperation in carrying out the details.

The experience of these surveys very often shows that the fullest use of our investment in street and highway width is not realized due to different standards or lack of standards used in the various jurisdictions or to the absence of a comprehensive plan for the entire route. The most striking example of such a condition exists on the Dixie Highway route extending south out of Chicago. On this heavily traveled thoroughfare a 6-mile stretch of 70 foot pavement is bottled up with a 40 foot throat at each end. It is easy to see that 30 feet of the 70 foot pavement gets very little travel. Plans are now under way, however, to remedy the condition.

The obstacles that exist on the more important highways of the region and the congestion resulting on days of heaviest

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travel is almost unbelievable to anyone not having had the experience of being a part of that congestion. One mile an hour is often the average rate of speed. Typical of these highways and the conditions found on them is Indiana's state road number 43, called the Dunes Highway, which runs through Hammond, Whiting, East Chicago and Gary around the lower end of the lake to Michigan City. Any summer holiday or Sunday will see this popular road filled with unbroken lines of motor cars extending from the Illinois state line on the west to Michigan City on the east. So close are they, at times it is said, that when a highway policeman in Michigan City holds up his hand for traffic to stop, motorists 35 miles westward shove on their brakes and come to a standstill.

The cause for the congestion on this particular road is due to the interference caused by the following obstacles recorded in the survey recently made over it: shoulders of loose sand along the country section of the pavement too soft to support cars forced to stop on account of tire or engine trouble; 18 railroad grade crossings in the towns along the route; worn-out, bumpy pavement; sharp turns and corners; a large ornamental square that forces all cars to slow down to twist around its corners; an improperly timed stop-and-go traffic signal; street cars that cut down the width of the roadway; and, unpaved street car tracks. Each obstacle along this route plays its part in adding to the delay and collects its tax in increased operating cost. If usable shoulders were constructed along the country section of the pavement it would be improbable that congestion would be materially relieved. The biggest part of the delay is due to the obstacles existing in the towns along the route.

On other main traveled roads of the region the same general conditions exist. The causes of congestion lie at the gateways and in the towns instead of on the country highway. It is interesting to note how the location of traffic obstacles have changed since the invention of the motor car. Everyone can remember how the motorist heaved a sigh of relief when his automobile pulled itself out of the rural mud and bumped onto the city pavement. But now it is different. The sigh is of regret as he leaves the smooth country highway and strikes a narrow worn-out city street and is confronted with a slow-moving local traffic, numerous traffic regulations and unregulated stop-and-go signals.

The examples mentioned above show why it is good highway engineering and business to locate main highways around towns and cities and build adequate connections to the business centers. In the past, municipalities demanded of state highway commissioners and county highway departments that

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paved roads be focused in to their business centers. The pendulum of public opinion, however, is now swinging in the other direction. Business men question the value received from through-traffic trade, but are unanimous in their opinion that anything that adds to the ever increasing, local traffic congestion is harmful to their business. To build highways around built up centers is exercising good foresight. Roads must be built to fit modern demands. The automobile which is being designed for faster speeds every year and which is increasing in numbers at an enormous rate, is now the ruling factor in highway location, design, construction and regulation.

In the interest of safety, economy and free movement of motor vehicles, the following conditions, classed as traffic obstacles, should be removed as soon as possible from existing highways and avoided in the building of new ones:

1. Local business districts or built up centers where traffic concentrates.
2. Jogs in alignment due to correction lines or other causes.
3. Blind curves, intersections and grdae crossings. Standardized warning signs and signals effectively placed to serve under the most adverse conditions lessens the danger at these points.
4. Sharp curves not properly banked and widened.
5. Curved approaches to subways or underpasses, viaducts and bridges.
6. Railroad grade crossings. Until funds are available to eliminate grade crossings on the main highways, crossing planks should be maintained flush with the rails and approaching roadways.
7. Car line streets. Street cars back up and stop traffic and their roadway pavements are seldom in good condition.
8. Rough, worn-out pavements.
9. Bottle-necks due to narrow roadways, bridges, viaducts, curves and subways or underpasses.
10. Short vertical curves on summits of hills.
11. Steep grades.
12. High crowns on roadways.
13. Slippery road surfaces.
14. Narrow or unusable road shoulders.
15. Sign, signal or light posts and buttons located in the center of intersections. They should be placed on the intersecting roadway center lines at the edge of the intersection.
16. Stop-and-go traffic signals improperly timed fo traffic.
17. Intersections with stop signs in all directio

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18. Roadways lacking painted centerlines or traffic lanes.

19. Unstandardized signs, signals and regulations. The Hoover Conference on Street and Highway Safety made up of representatives from the entire country has made great progress in this direction.

20. Route, warning and street signs ineffectively placed, out of range of driving lights, not illuminated or invisible at night. With the rapid increase in numbers of motor cars throughout the country, traffic regulation and control is becoming more necessary and exacting. Signs and signals are the means for making regulation and control possible, provided, they are so placed to be effective under the most adverse conditions—darkness and a wet or icy pavement. To test the value of a sign system, drive under the conditions mentioned and see if all signs are easily visible and all stops can be complied with without skidding past the point of danger.

ROADSIDE WEED CUTTING

By Joseph F. Crowe,
Porter County Highway Superintendent.

The cutting of weeds along the roadside should be given serious attention by all County Highway Superintendents. If weeds are permitted to grow along the road we find that in a few years the drainage is seriously interfered with and the roads do not dry out as rapidly in the spring as they should. Roadside weeds are unsightly, hold snow in the winter time and cause unnecessary work in snow removal.

There is considerable disagreement among Highway Superintendents and farmers as to whose duty it is to see that the weeds along the roadside are cut. I am a farmer myself and believe that it is my duty to keep the weeds cut along the road in front of my farm. I take this stand for three reasons:

1. The law states that all land owners shall cut down or cause to be cut down, and destroyed, all weeds along the road bordering on their land.

2. It improves the appearance of any farm by having a roadside neat and clean.

3. It is not fair to the industrious farmer, who cleans his own roadside, for the county to spend some of its meager gravel road repair funds in cleaning up the roadside where the lazy farmer fails to do his duty.

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PUBLICATIONS OF THE ENGINEERING EXTENSION DEPARTMENT

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*CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

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Mimeographs

The following material has been issued in mimeograph form:

FOUNDRY CONDITIONS IN INDIANA, R. E. Wendt, 1922.

STATUS OF CITY PLANNING IN INDIANA, G. E. Lommel, 1923.

CITY PLANNING AND THE REALTOR, H. M. Dickman, Evansville, Indiana, 1923.

OUR HOUSING PROBLEM AND ITS RELATION TO CITY PLANNING, L. C. Smith, University of Wisconsin, 1923.

THE CITY TOPOGRAPHIC SURVEY IN CITY PLANNING, R. H. Randall, Toledo, Ohio, 1923.

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Proceedings

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Industrial Conference

Held at

PURDUE UNIVERSITY

June 1, 1926

BULLETIN NO. 15

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LAFAYETTE, INDIANA

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PURDUE UNIVERSITY

Lafayette, Indiana

Purdue University is a state institution. It owes its origin to the Land Grant Act of Congress of 1862, otherwise known as the Morrill Act, and to the enactments of the legislature of Indiana of 1865 and 1869. It is maintained principally by state appropriations, supplemented by various Federal grants.

The institution began its work in 1874 and derives its name from John Purdue, a philanthropic and public-spirited citizen of Lafayette. Graduate and undergraduate instruction is offered through the Schools of Agriculture, Applied Science, Chemical, Civil, Electrical and Mechanical Engineering, Home Economics and Pharmacy.

The University also maintains extensive Experiment Stations in Agriculture and Engineering and also carries on state-wide extension work in both of these fields.

The teaching and scientific staffs of the University number approximately five hundred. The University has forty principal buildings and controls over four thousand acres of land.

For catalogues and information, address

THE REGISTRAR,
Purdue University,
Lafayette, Indiana.

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LAFAYETTE, INDIANA
JUNE, 1926

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PURPOSE OF THE CONFERENCE

Executives representing most of the leading industries of Indiana and Governor Ed Jackson gathered at Purdue University on June 1, 1926, in a meeting which gives promise of ushering in a new era in Indiana industrial development. They were the guests of Mr. David E. Ross, Manager of the Ross Gear and Tool Company and a Trustee of Purdue University, who bore all expenses connected with the calling and planning of this conference, because of his interest in Purdue University and his appreciation of the fact that research in science and engineering forms the foundations of modern industry. The industries of Indiana and Purdue University are extremely fortunate in possessing among the leading citizens of the State, Mr. David E. Ross—a combination of inventive genius, business manager, engineer, philanthropist and idealist—a man who thinks in large units, visualizes the needs of the day and plans the means to meet the new demands of the times.

At this conference plans were proposed for a great industrial research laboratory at Purdue University to meet the growing demand of Indiana industry for fundamental information. Realizing that research, with the basic facts which it supplies, is the food on which any business thrives, those present endorsed without exception the plan for a research laboratory and approved the suggestion that a committee be named from their group to legalize such a project.

The visitors spent the afternoon inspecting the laboratories, shops and equipment of the University and getting acquainted with what the University is doing for the American Railway Association in its airbrake tests, for the Indiana Limestone Quarrymen's Association and for other groups that are co-operating with the institution in research work. The tour included also the farms, where demonstrations were given for the various lines of research in agriculture. Each man saw the results of agricultural research and what it has done for Indiana farmers; to each was presented a bird's-eye view of the services being given the state by the institution with its present facilities.

Governor Ed Jackson in opening his address stated: "I regard this as one of the most important meetings, if not the

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most important, I ever had the opportunity of attending, in my experience, in the State of Indiana."

The address of each speaker at the conference is printed in this bulletin in order to refresh the memories of those who were present and to give first-hand information to those other Indiana business leaders who were unable to attend. This conference is only one of the many benefactions which the University and the state owe to Mr. David E. Ross.

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LIST OF GUESTS AT THE CONFERENCE

Hon. Ed Jackson, Governor of Indiana
David E. Ross, Ross Gear and Tool Company
Edward C. Elliott, President, Purdue University

Anderson

Noble Dean, General Manager, Dean Pump Company
Hugh Hill, President, Hill Standard Company
Ed. Neiper, General Manager, Ames Shovel and Tool Company
Harry O'Conner, Manager, American Steel and Wire Company
T. E. Wilson, Manager, Remy Electric Company

Attica

Roy J. Harrison, Vice-President, National Car Coupler Company

Batesville

J. A. Hillenbrand, President, American Furniture Co., and Trustee, Purdue University

Bedford

H. S. Brightly, Managing Director, Indiana Limestone Association
F. S. Strong, Indiana Limestone Company

Brazil

H. Hull, Brazil Clay Company
W. A. Laverty, Brazil Clay Company

Buffington

Joseph K. Kempser, General Superintendent, Universal Portland Cement Company

Crawfordsville

John A. Johnson, President, Johnson Acetylene Company
Bruce Luckett, President, Shale Brick Company

Connersville

C. C. Abbott, Vice-President, P. H. and F. M. Roots Company

Chicago, Illinois

T. A. Hamilton, Vice-President, Pennsylvania Railroad
H. R. Kurrie, President, Chicago, Indianapolis and Louisville Railroad

East Chicago, Indiana

W. B. Gillies, General Manager, Youngstown Steel and Tube Company
F. A. Lorenz, Chief Engineer, American Steel Foundries
W. A. Maxwell, Superintendent, Inland Steel Company
Charles H. True, Vice-President, Superheater Company

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Evansville
- O. E. Gage, Manager, Bucyrus Company
- W. H. Noelting, Vice-President, Faultless Castor Company

Ft. Wayne
- F. H. Beebee, Vice-President, West Gas and Construction Company
- R. M. Feustel, President, Indiana Service Corporation
- Walter B. Goll, General Manager, General Electric Company

Hammond
- George Hannauer, Vice-President, New York Central Railway
- Morse Dell Plain, Vice-President, Northern Indiana Gas and Electric Company

Hartford City
- F. M. Forkner, Hartford City Paper Company

Indianapolis
- W. H. Arnett, General Secretary, State Chamber of Commerce
- H. C. Atkins, President, Atkins Saw Company
- Arthur Baxter, President, Keyless Lock Company
- Carl Gibbs, Manager, National Malleable Casting Company
- A. M. Glossbrenner, Treasurer, Levy Printing Company
- H. A. Glover, Vice-President, Consolidated Coal Company
- Walter Harding, President, G. and J. Tire Company
- Chas. L. Henry, President, Indiana Utilities Association
- H. C. Huffstetter, Indiana Sand and Gravel Company
- O. S. Iles, President, International Machine Tool Company
- William Insley, President, Insley Manufacturing Company
- Hon. Ed Jackson, Governor of Indiana
- Mrs. Ed Jackson
- Col. Richard Lieber, Director, Indiana Conservation Commission
- Mrs. Richard Lieber
- J. K. Lilly, President, Eli Lilly Company
- Howard Schurmann, President, Independent Pipe Company

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F. M. Smith, Secretary, Indiana Manufacturing Association
Arthur Stanworth, Stanworth Tool Company
W. C. Starkey, Vice-President, L. G. S. Devices Corporation
George Torrence, Vice-President, Link Belt Company
Guy Wainwright, Vice-President, Diamond Chain Manufacturing Company

Kokomo

C. E. Henderson, Manager, Pittsburgh Plate Glass Company
Mrs. C. E. Henderson

Lafayette

W. A. Callison, Superintendent of Motive Power, Chicago, Indianapolis & Louisville Railroad
G. I. Christie, Director, Agricultural Experiment Station, Purdue University
Stanley Coulter, Dean of Men, Purdue University
Edward C. Elliott, President, Purdue University
E. Gruenewald, Works Manager, Ross Gear and Tool Company
C. F. Harding, Professor of Electrical Engineering, Purdue University
W. K. Hatt, Professor of Civil Engineering, Purdue University
J. D. Hoffman, Professor of Practical Mechanics, Purdue University
T. R. Johnston, News Service, Purdue University
J. F. Keller, Engineering Extension, Purdue University
W. A. Knapp, Engineering Extension, Purdue University
H. G. Leslie, Secretary, Alumni Association, Purdue University
F. C. Lewis, General Superintendent, Chicago, Indianapolis & Louisville Railway
Robert McMahon, News Service, Purdue University
Miss Mary Matthews, Professor of Home Economics, Purdue University
Mrs. Virginia C. Meredith, Trustee, Purdue University
M. B. Morgan, Mayor, West Lafayette, Indiana
H. C. Peffer, Professor of Chemical Engineering, Purdue University
A. A. Potter, Dean of Engineering, Purdue University

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A. R. Ross, Mayor, Lafayette, Indiana
David E. Ross, Trustee, Purdue University, and Manager, Ross Gear and Tool Company
J. H. Skinner, Dean of Agriculture, Purdue University
R. B. Stewart, Controller, Purdue University
James Wiselogel, President, Peerless Wire Goods Company

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Finley T. Mount, President, Rumely Company

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F. B. Wilkinson, President, Logansport Machine Company

Marion
Henry L. Erlewine, Treasurer, Marion Machine Foundry and Supply Company
L. R. Lindley, President, Lindley Box and Paper Company

Michigan City
W. J. Dickinson, Manager, Pullman Car Company

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George W. Miller, President, Dodge Manufacturing Company
S. T. Nelson, General Manager, Sullivan Machinery Company

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Whiting
Dr. R. E. Humphrey, General Manager, Standard Oil Company

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INDUSTRIAL RESEARCH FROM THE MANUFACTURER'S VIEWPOINT

By David E. Ross, Vice-President and General Manager, Ross Gear and Tool Company, Lafayette, Indiana, and Trustee, Purdue University.

I believe you all realize that Indiana industry is very well represented here tonight. For several years I have been wanting to invite you here and as a trustee spending your money on the University to tell you what this University should mean to you and what you do mean to the University.

My first interest is in the youngsters we are bringing through the University. I might stop to say that first of all, if students are to enter the institutions of higher learning, they must obtain the proper basic foundation in the grade schools and high schools. But tonight I want you to hear something of the higher education we are giving them, my effort being to interest you in the necessity for broader research here, both pure and applied. Indiana higher education today is divided among three state institutions. Indiana University is doing a wonderful work in its field, training for citizenship and bringing on a class of professional people that will raise the cultural and ethical plane of the state. We are not, in any particular, encroaching on the work of that institution, neither is it duplicating any of the work which we give here at Purdue. The Normal Schools are preparing teachers for their life work. The work done by both Indiana University and the Normal Schools is of the utmost importance for the welfare of the state.

However, I am particularly interested in stating to you the case of this University and the part it can play in solving our problems if it is provided with a superior staff, adequate buildings, and sufficient funds for equipment. Under these conditions I hope that our students will have such facilities that they may discover their natural aptitudes and become distinguished citizens and efficient workers for the betterment of the state.

Now you have inspected the equipment the University has, and you certainly realize what things we do not have. My personal opinion is that for a technical school like ours a big

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mistake has been made—namely, the omission of the item of obsolete equipment as a charge for the operation of the University. Some of the equipment you saw today you industrial men would not have in your own plants. It is out of date—and yet we have never considered it as an operating expense against the University and the state. We should now face the truth about this obsolete equipment. You do not expect that your own equipment will go on forever at its full value. Purdue has achieved a great reputation in experimental work and research, but most of our investigations are hampered by lack of modern facilities. Greater and better things can be accomplished if buildings and funds are provided. Our faculty and students should have the best machinery with which to do their work.

We have here at Purdue University a faculty of highly trained men; and until you are a trustee of the University and get a line on their personalities and their aspirations you cannot begin to realize what it all means. Our faculty people are not thinking in terms of salary and money. They are devoting their lives to the training of the youngsters sent to the University. You could be of special benefit to them if you could get closer to them and get their viewpoint; and they could certainly be of greater benefit to you if they could get your viewpoint.

Adequate research facilities here would be an inspiration that would lead a student on and develop in him a real desire for scientific attainment. At the same time, every research discovery affecting Indiana products would mean more wealth, larger population, and a more contented citizenship. It is through such discoveries that the luxuries of the millionaire of one generation become the ordinary necessities of the working man of the next generation.

When the World War came on, we did not know how to make dyes. We had left this whole field to the Germans. At that time this country confiscated the German patents and we started making dyes. We did not dig out the basic facts; it was *not* our own research that promoted the making of dyes in this country, but we were the beneficiaries of the original work of others.

Sometime about 1890 a group of German industries banded together and founded a research laboratory. The project in-

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volved chemical corporations, arms corporations, ball bearing factories, ammunition works; and out of the laboratory came a wonderful benefit for those industries participating, through the application of the results of wide research and tireless experiment to their various problems. And you know how marvelously, with the advent of the World War, these and other scientific investigations of the Germans promoted their cause.

This winter it was my great pleasure to take a trip expressly for the purpose of studying the research laboratories of several companies. The A. T. and T. Company has a research laboratory which employs approximately 3,600 people. I visited the General Electric laboratories in Schenectady, as well as the Westinghouse laboratories and the Mellon Institute at Pittsburgh. The latter, operated under the management of the University of Pittsburgh, I believe our state might well copy; and I feel that those here will agree with me that such a headquarters for research should be located at Purdue University. I visited the General Motors and Henry Ford plants. Mr. Ford is doing a lot of applied research in the field and some experimental work in the laboratory. The process of making plate glass called the continual process is one of the wonderful Ford developments. To illustrate Mr. Ford's way of doing things—he instructed one of his men to investigate the preparation of flax by machinery instead of by hand. His instructions ran like this: "It is your job to see that flax is pitched into a machine with a pitchfork." I saw that very equipment in operation: flax is pitched into the machine with a fork; it is gradually worked into threads, goes on to the weaving machine, passes under the composition rolls, and finally comes out as imitation leather.

The raising of flax in Indiana would add to the diversity of our farming and at the same time would provide us with a new industry.

The same thing would be true of the raising of the soy bean, which has come into this state quite recently. We have been importing soy bean oil from China, but we can as well produce it ourselves. And I am told that synthetic milk can be made from soy beans. Furthermore, the soy bean is one of the best agents for the enrichment of the soil.

I am told that four-fifths of the imitation bone and horn

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used in this country is imported from abroad. This is made entirely from casein, which is a milk by-product—and think of the skimmed milk that is wasted in Indiana every day!

Our great state has a wealth of natural resources. I understand that our state stands about fourth in the production of coal. Think of the great opportunity for research by our university experts, the opportunity to assist in the development of industries which will turn our coal into coke, liquid fuel, gas, chemicals, dyes, and many other products. No longer will our chimneys shoot out great quantities of black smoke. Our cities will be cleaner and better places in which to live; and at the same time new industries will add to the wealth of the state—for the possibilities for the development of new uses for Indiana coal are so numerous that I would not attempt to enumerate them.

Again we have the great oil-bearing shale districts of Southern Indiana, offering a wonderful opportunity for ceramic industries that might obtain part or possibly all of their fuel from the oil in the shale itself. Or, if coal were used exclusively as fuel, the oil could be handled as a by-product.

Now as to the meaning of all these statements about industry and agriculture. Let me say to you that if we want to increase the wealth of the state we must strive for the sort of broader production and greater diversification I have outlined. I hear from the farmers every day that their men are coming into the industries to work. The industries cannot keep on indefinitely pulling men from the rural districts without getting a reaction sooner or later; for, although you may not realize it, the farmer's problem is your problem, and on account of the restriction of immigration you cannot continue to rob the farm without economic punishment being meted out to you later on.

The great electric companies are desiring to promote greater power consumption on the farm, but the first thing the farmer must know is how to use that power profitably. Germany has used power on the farm with a considerable amount of success, the farmer and his family constituting a small, isolated factory for the production of various articles in their spare time during the winter months.

Now, scientific research can make this State of Indiana the type of commonwealth we desire it to be. New discoveries

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will make new industries, and greater prosperity will help us to induce greater numbers of our engineering graduates to stay here in Indiana for the developing of their careers, and to take their place in our body politic.

I think a lot of the youngsters we are bringing on here. They are being trained for citizenship. We should give them every opportunity, and to do this we must provide for the continued progress of our industries and for the introduction of processes for the development of our natural resources in order that these students may have a broader outlet for their trained energies.

I trust that beginning with the second fifty-year period of its existence this university will not merely train people as employees but will bring forth the type that will go ahead into original research and with the proper initiative and persistence will accomplish new developments within the state; the type that will find for the farmer's products uses which he has never dreamed of before, will add to our productive wealth, and will give our people profitable employment. I believe there is a real, definite service that can be rendered at this great scientific institution, should it be made the headquarters for a fully equipped research laboratory. This service would be measurable in dollars in a very few years. I am not so much interested in the dollars as I am in the students and their future; and yet those same dollars are the means by which we are enabled to operate the University.

Shortly after the discovery of the rate of flow of electricity through a conductor a member of Parliament asked Mr. Faraday, the discoverer, "What does it amount to?" Faraday studied over his answer and finally said: "It is something you will tax some day!"

I believe that after considering all these things, the leaders of the industries of Indiana will realize that Purdue University can accomplish greater and better things than ever before, and I feel certain that you who are here tonight will gladly lend your support in making the buildings and funds for this research project a reality.

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PURDUE AND LIMESTONE RESEARCH

By H. S. Brightly, Managing Director, Indiana Limestone Quarrymen's Association.

I esteem it a great privilege to address this distinguished body of educators and industrialists who have come here tonight in response to the invitation of Mr. Ross. At the same time I feel keenly the responsibility that is attached to such a privilege.

I am going to tell you something about the necessity for research as we see it in the development of modern industry, and something about the part it plays in the very survival of individual industries in face of the keen competition that exists today in nearly all fields of industrial endeavor.

In order to make this statement clear, I am first going to give you a little history of the development of the building stone industry, which I have the pleasure to represent as Managing Director of the Indiana Limestone Quarrymen's Association.

I do not believe that more than a small proportion of the people who reside in Indiana realize the importance of the limestone industry of this state, located in Lawrence and Monroe Counties, not only to Indiana, but to the entire United States. In order that those here tonight may gain some idea of the extent to which builders are now dependent upon the stone produced in southern Indiana, I should like to say that these two counties furnish about thirty-five per cent of all the stone used throughout the United States; or, considering only the finished cut stone, Indiana's percentage is over sixty-five!

Following the close of the late war, Indiana building limestone industry was practically "down on its back," and the operators got together to see what could be done to restore their product to the dominating position in the natural stone field which it is entitled by merit, structural and aesthetic, to hold. To cope with this problem, our association was organized for co-operative promotional work. It was thought at first that to advertise was the thing to do, and that this alone would be effective at a time when competition was very severe owing to the fact that the construction of buildings was being revived following the cessation of industrial activities associated directly or indirectly with the war.

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However, architects and engineers, in response to the industry's promotional effort, stated to its representatives that Indiana limestone did not need much advertising as far as they were concerned; they knew of its merits as a building stone; what they needed was that this industry inform them more about the physical properties of the stone and tell them how they could use it economically and detail it most effectively in connection with modern methods of building construction. What the architects and engineers wanted was technical information—not advertising; let the industry's advertising, they said, be directed to prospective builders in the various fields of construction.

In order to establish a department for furnishing architects and engineers with the information they desired, the Service Bureau of our association was then organized. It was soon found that many, if not most, of the inquiries addressed to this service department were on technical subjects, and that in order to establish the facts needed, technical investigations and research were necessary. Structural problems arising out of modern systems of building were constantly being brought to the attention of this department—problems of an engineering nature, which the stone industry had never had occasion to study and solve as a part of its sales effort.

In explanation, let me briefly outline the development of the modern type of commercial structure, more particularly the tall, skeleton-frame type. When buildings of this kind first came into use, the stone industry had no service or technical department and no effective means of developing the use of its product in a way that appeared to fit in with the requirements of the new methods of construction.

The stone producers generally thought in terms of masonry construction and were not ready to adopt the changes in structural principles which the development of the skeleton-frame structure imposed upon them.

The result of this was that clay products came to be used most extensively for the walls of these structures. In fact, the development of the terra cotta industry from its small beginning almost paralleled the development of the structural-steel, skeleton-frame building; and for a time the decision to erect that type of building was almost synonymous with the adoption of terra cotta for the facings.

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It is of comparatively recent years that the value of stone for facing the enclosure walls of tall buildings has become universally recognized, and that its use for that purpose has become widespread; and it was, as I have indicated, this new use for stone, involving many problems unfamiliar to architects and engineers, which necessitated the taking up of research by our service bureau.

A more thorough knowledge of the physical properties of the material was particularly necessary, by reason of the fact that the new usage, since it employs stone as a comparatively thin facing for the walls of tall buildings, places the properties of the stone under a severer test than the usage in walls of simple masonry structure ever causes them to undergo. It was found that in these buildings, under certain conditions, the stone was becoming over-stressed and cracked, in spite of the fact that it possessed a crushing strength of from six to eight thousand pounds or more per square inch—many times greater than any load which would ever be placed upon it in the designing of building structures. That there must be some unusual forces at work, causing strains to be set up, was quite evident; the tremors set up in tall buildings by wind action and the unequal contraction and expansion due to temperature changes and to exposure were factors which must be coped with.

Again, it was found that as a result of the extensive use of Portland cement for mortars and for concrete, staining of the stone was often developing where considerable moisture was present, and that in many other ways present-day building practice was imposing conditions of service which had never before been contemplated.

All these findings of the service department pointed to the great need for scientific research. And thus, through the Association, the operators engaged in the quarrying and milling of Indiana limestone in the Bedford and Bloomington districts came to understand the difficulties which it was imperative that they surmount before they could broaden the market for their product in the various building fields, and to realize the absolute necessity for their engaging in research activities, not only for developing their business further, but also for retaining what prestige they had enjoyed in the past.

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From this outline I think you will at once gather the importance of research in the history of the industry with which I am connected—and its importance is certain to become increasingly greater. With Indiana limestone amounting to something over eighty-five per cent of all building limestone, and totaling over eleven million cubic feet during any normal year, there is pressing need for considering the questions of waste and of potential by-products.

As to waste—there is at the present time a tremendous waste in the production of Indiana building stone—a waste that would not be permitted in any other country of the world. Today our industry is throwing into the dump heap not only stone which might be salvaged for other than building uses, but stone of a quantity and of a grade which would have been welcomed by the builders of the great Gothic cathedrals in Europe—simply because the size of the pieces does not warrant the working of them, considering our system of intensive competition and the existing high cost of production and transportation. Such a waste is of itself a national crime. Allow me, in justice to our industry, to repeat the reason for it—namely, that the cut stone trade, quite naturally, wants only large blocks of regular shape, because they cost less to work up. Yet a great portion of the smaller and more irregular blocks often contain the very finest grade of building stone. They should be worked up in some form, and put to use. That again is a problem of research.

The high cost of transportation has prevented the use of a great deal of this material, for it is a fact that if the quarry operators were to give it free of cost, and load it onto cars, the steel manufacturers at Gary, as close as it is to our quarry district, would not accept it and pay the freight charges, since by water transportation they can obtain a limestone at a lower cost from points on the Lakes. This economic situation is an unfortunate one, but one which can be offset by the discovery, through research, of new uses for the by-product of quarrying.

A very important factor in connection with the nation-wide use of our stone is the extent to which quarrying and cutting are now done by machinery. Today, the huge quarry blocks are hewn out of the ledge, transported, sawed, planed, cut, and worked into the various shapes required by the building

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trade—all very largely by machinery. By this extensive use of highly developed and economical machine-production methods, the increasing cost of labor has been met and the finished product held down in price to a point where it can compete successfully with other building materials in most parts of the country. At this moment you can find Indiana limestone in buildings erected in cities throughout the country from the Atlantic to the Pacific coasts, in the remote corners of the country, and across the line in Canada.

Back in the old days the largest portion of the stone produced was used in the construction of court houses, postoffices and other monumental structures of that type. During late years there has not been any great volume of this sort of construction; nevertheless, the industry has been developed to the high point which I have already indicated, through the extension of the use of stone in commercial and residence construction, and through its continued wide use in the construction of educational buildings.

Furthermore, when the Government, through its new building program, renews its normal building stone requirements, there will come a substantial increase in the market which the great Indiana field will be called upon to supply.

An increased demand for building stone means an increased production of waste material which by research may be converted to some use profitable alike to the commonwealth in general and to the railroads and other industries that are necessarily associated with any increased output of this sort.

You will therefore see that there are a great many weighty problems before our industry which can be solved only by cooperative work or by well organized corporate developments, since their solution involves an expenditure quite impossible for the small operator. In that connection I may say that just recently a forty-million-dollar corporation has been formed and has acquired a number of the more important quarrying and milling plants in the district in order to provide a means of developing further this great industry of southern Indiana.

I think I am safe in saying that this is the largest corporation that has ever been formed within the state. Am I not right, Governor? [To this question Governor Jackson responded, "Yes, you are right."] The idea back of this cor-

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poration is to serve the building public of the United States to better advantage: to see that there is less waste of this fine natural product, and that as much as possible of the waste material is converted into appropriate uses.

This corporation will unquestionably be deeply interested in the possibilities of research; and the state, in helping such an organization to conserve a natural resource of this sort, will be helping not only the organization but itself as well. The state has helped agriculture in a large way—then why not industry also? For if the state makes its industries more prosperous, it of necessity increases the prosperity of all its people.

Those of you who made the trip through the laboratories this afternoon saw the very interesting series of tests which are being conducted by Doctor Hatt on the fatigue of concrete. Our industry is carrying on studies of a similar nature in order to determine the fatigue of natural stone, an investigation which I do not believe has ever before been conducted.

You also had an opportunity this afternoon of inspecting some of the tests which are being made in behalf of our industry by the Purdue Engineering Experiment Station in connection with its study of the staining problem to which I have already referred. You saw a number of stone slabs in which the varied effects of staining were quite evident. This, however, let me say, showed our product at its worst, because in these tests everything has been done to create the exaggerated conditions that are necessary for conducting a complete investigation. The staining of the stone is being produced by artificial methods in an endeavor to discover its primary causes and an effective means of preventing it.

The co-operative arrangement which our industry has with the Purdue Engineering Station has now been in effect for several years, and much valuable information has been developed. This information on building stone, its properties, and its effective use is of direct benefit not only to us here in Indiana but also to the building public throughout the entire United States. And this is just one of the problems which the Station has undertaken in co-operation with us.

What is being done in the stone industry through research is but representative of what is being done or can be done in all industries. In regard to the importance of research to

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industry in general, I feel that I cannot express the idea better than by quoting a tersely-worded passage from an address by Dr. Arthur D. Little, delivered before the American Institute of Chemical Engineers last June: "The price of progress is research, and this alone will assure the security of dividends. No industry can hope to ignore research and live."

All of us here tonight are interested in research, or should be if we are not. And the idea sponsored by your trustee, Mr. Ross, that the real place for research in this state is here at Purdue, is a very good one. The plan has a further advantage in that it will interest our students in research and will place them in definite contact with the industries of the state. The chances are that as a result a great many of our young men will take up their life work here among us, rather than go outside to seek employment. This of itself is an important consideration.

I think that those who are here as representatives of the other industries of the state will agree with me that it would be a great thing if Purdue University could in a larger way be made the scientific research headquarters for the industries of the entire state—which I believe is the idea that Mr. Ross has in mind.

PURDUE UNIVERSITY AND INDIANA INDUSTRY

By A. A. Potter, Dean of the Schools of Engineering and Director of the Engineering Experiment Station, Purdue University.

While the United States has less than one-twentieth of the population of the world, our inventors are responsible for more than two-thirds of the epoch-making inventions which we are now enjoying. The telephone, the telegraph, the electric light, the moving picture and the talking machine—in fact, most of the wonders of our age—are the results of American inventive genius. Our people have, however, added very little to fundamental scientific knowledge.

Our country represents only about one-fifteenth of the land area of the world, but our natural resources enable us to produce a very large share of the world's supply of oil, coal,

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iron, steel, copper, and aluminum. These wonderful natural resources, combined with the genius of our people, have enabled us to produce in this country a material welfare which is the greatest in the entire world, but on the other hand, we have had to depend largely upon other countries for new scientific knowledge.

In the earlier days of the development of industry much dependence could be placed upon the individual inventor, but with the increased size and complexity of modern industry it is not practical to wait for chance discoveries by men of genius. Leaders of industry are convinced that research laboratories must be used to acquire new and exact knowledge of facts, to develop new products, and to lower manufacturing costs. Research is of value in improving old industries and in building up new ones.

So much has been accomplished through invention that many people are of the opinion that everything worth while has been discovered and that the engineer is concerned only with the application of already existing knowledge. This idea is erroneous, as industry is confronted today with many problems of the most serious nature, which can be solved only if the best brains of the country are constantly at work on research.

Several of the leading European nations recognized many years ago that technical research is a governmental function and one of the soundest forms of national investment. They were ready to encourage investigations of immediate value in warfare, as well as researches to further industrial development during peace. They realized that industrial supremacy is dependent upon proper co-ordination between science and industry.

Research can be carried on either by industry, or by educational institutions such as Purdue University, working in co-operation with industry. Research work carried on by universities has several advantages as compared with that carried on in industrial laboratories: university research workers are free from interruption; they are in an atmosphere sympathetic to research; and their work reacts most beneficially in improving the main output of those universities—trained engineers. Industry needs engineers who will extend the frontiers of knowledge and who will develop new

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processes for the conservation of our resources and for the elimination of waste. These things can be accomplished if industry will bring its research problems to our universities as is the case in Germany, where very extensive research work is being carried on in the technical universities.

Closely related to undergraduate and graduate instruction is the pursuit of research, which forms the foundation of the university structure. Research work, besides being of value to industry, has a stimulating effect upon students and is most useful in keeping teachers in close touch with industrial practices and progress.

Purdue should certainly be the technical laboratory of our smaller industries, and we hope that, as time goes on, every one of the industries of Indiana will be willing to recognize technical research at Purdue, where attention can be given to the advancement of both science and industry and to the training of research workers for the future. Manufacturers should be encouraged to spend a definite percentage of their profits for technical research in order that they may, by the use of science, effectively combat competition. Our industries must concern themselves with such researches as will enable them to cheapen their manufacturing processes, to utilize low-grade and waste products, and to develop new and useful articles of commerce.

Purdue University has at present about 2,000 young men who are studying civil, chemical, electrical, and mechanical engineering. The most important function of the University is to develop these 2,000 students into engineers who have the ability to think clearly, the technical knowledge to enable them to be of value to your industries, the personality to make them acceptable to others, the traits of character that make for nobility of action, and sufficient idealism to take an active and leading part as citizens of our free country. Each one of these students must be given every opportunity to develop as far as his talents and aptitudes will permit.

Purdue University, however, is not satisfied to have teaching and the conservation of knowledge as its only functions. This university has realized for over a third of a century that efficient engineering instruction must find expression in extending the boundaries of engineering knowledge through

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research. We feel that it is necessary for us to add something to fundamental knowledge.

The research relations between Purdue University and industry are shown by the following facts concerning the Purdue Engineering Experiment Station:

(a) The Station is studying the causes and prevention of discoloration of Indiana limestone, in co-operation with the Indiana Limestone Quarrymen's Association.

(b) In co-operation with the automotive industry, it is making investigations of automobile carburetors, manifolds, spark plugs, pistons, piston rings and cylinders; it is also going into special problems of steering, detonation, supercharging, fuels, etc.

(c) Standardization of tractors is being investigated in co-operation with tractor manufacturers and the United States War Department.

(d) Study of insulators for high voltages (up to 600,000 volts) has been undertaken in co-operation with manufacturers of insulators.

(e) Tests of construction materials and of brake shoes, pulleys, insulators and a variety of other devices for industry in general have been made.

(f) The Station is co-operating with the mining interests of Indiana in a study of the steaming qualities of Indiana coal and in the developing of methods for the improvement of its quality.

(g) It is carrying on investigations in co-operation with the Indiana Sand and Gravel Association.

(h) It is co-operating with the American Railway Association in an investigation of power brakes and power brake appliances. This study was undertaken on March 1, 1925; and the amount expended by the co-operating agency from that date to June 1, 1926, has been in excess of $100,000. The investigation will involve an additional expenditure of about a half million dollars before it is completed.

(i) The American Railway Association has also contracted to start a co-operative study of draft gears at Purdue University. In connection with this study there will be used a drop testing machine equipped with a 27,000-pound weight.

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(j) The Station is co-operating further with the railroads in studies of brake shoes, rail joints, and special railway equipment.

(k) It is co-operating with the telephone utilities in investigation of buried lead cables, and with electric light and power utilities in studies of high-voltage insulators, of electric meters, and of the emergency braking of electric cars.

We are very anxious that Purdue University should become the State Bureau of Standards as well as the Indiana "Mellon Institute for Industrial Research." This arrangement will give the industrialists of Indiana a chance to bring their live problems to us for solution and will aid our industries in developing new lines of manufacture. You industrialists of Indiana can make this dream of ours a reality.

The industries and utilities of Indiana have a clear-cut obligation to provide Purdue University with special equipment and funds for the solution of new problems through research in order to be certain that the engineers of the future will have intellectual curiosity and the ability to extend the frontiers of engineering knowledge.

In addition to the teaching of students and the carrying on of investigational work of value to the State of Indiana, we have been using our facilities to bring engineering knowledge to the people of the state through lectures, conferences and short courses. The Engineering Extension Department of Purdue reached over 17,000 Indiana people this year. We feel that this type of engineering extension work is highly valuable to the industries and to the people of the state.

Your Purdue University is the second in size among all of the engineering colleges of this country. You have the power to make it second to none as a training center for engineers and as a research agency for Indiana industry.

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PURDUE UNIVERSITY AND RAILWAY RESEARCH

By H. A. Johnson, Director of Research, American Railway Association.

Mr. Ross has requested me to come here this evening and tell you why the American Railway Association—which represents, as you know, practically all of the railroad and private trolley lines in the United States and Canada—decided to carry on its investigation of power brakes at Purdue University. Before trying to answer this question, I want to explain in a few words why the American Railway Association is carrying on this research work. In the last few years, the size, both in the number of cars and in tonnage, of the freight trains operated in this country has increased very rapidly. Those not directly connected with the railroad industry may not have noticed the extent of the increase, but trains over one hundred cars in length, up to a hundred and twenty-five or a hundred and forty cars, are now quite common. This is largely due to the development of higher efficiency of the steam locomotive, which development has been greater in the last eight or ten years than in any other similar period, notwithstanding the discussion of electrification of the steam railroads. The length of the train has increased with the size and pulling power of the locomotive. It is safe to operate trains only of such length and weight and only at such speeds as will permit their being controlled with safety to the crews and without damage to the cars or lading. In other words, when a train has been set in motion adequate facilities must be at hand for controlling its speed and bringing it to a stop when desired.

During this period of development we entered into the World War and the railroads were taken over by the federal government. All efforts were directed toward winning the war, and maintenance of rolling stock was somewhat neglected; so that when the railroads were turned back into private control many problems concerning operation required immediate solution. One of these important problems was that of the power brake. The Bureau of Safety made a survey of the power brake situation, including road demonstrations, and reached the conclusion that an improvement in the present standard freight-train power brake is desirable and

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must be immediately made. As you know, the Bureau of Safety is that part of the Interstate Commerce Commission which is responsible for the safety of the employees of the railroads and for the safety of the passengers carried. All accidents of any consequence are reported to and investigated by the Bureau of Safety. Many of the orders of the Interstate Commerce Commission are based upon investigations and reports of that bureau. Its recommendation regarding power brakes, accordingly, was of the greatest importance; for if the Interstate Commerce Commission issued an order based on this recommendation, the railroads would have to purchase and install a new air-brake system on all freight cars. As there are approximately two and three-fourths million freight cars in service, the expense to the railroads would amount to nearly one billion dollars.

During the conduct of the tests by the Bureau of Safety, the representatives of the railroads and of the air brake manufacturing companies were present and made observations. The railroad representatives did not agree with the conclusions reached by the Bureau of Safety, and naturally the manufacturers' representatives favored their respective types of equipment.

In July, 1924, the Interstate Commerce Commission issued a preliminary "report and conclusions" containing tentative specifications and requirements for power brakes. These specifications were not acceptable to the representatives of the railroads. After considerable discussion the American Railway Association agreed to undertake a thorough and unbiased investigation into the entire subject of power brakes to determine what, if any, improvements were necessary for the safe and economical operation of trains, upon the condition that the Interstate Commerce Commission would hold its contemplated order in abeyance for a reasonable length of time. The American Railway Association selected a Director of Research who was not directly connected with any steam railroad and who had never been in the service of any manufacturer and charged him with the responsibility of conducting this investigation in a manner which would be satisfactory to all of the interested parties.

Now that I have shown the conditions leading up to this research work and the far-reaching effect of its results, we

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are ready to consider why Purdue University was selected to carry on this work. There are several reasons which may be given.

For many years Purdue University has been co-operating with the American railways. This co-operation dates back to the time when Dean Goss was at Purdue. Dean Goss was very close to the managements of the railroads and carried on a great deal of experimental work for them, especially on locomotive development. He had been instrumental in inducing the Master Car Builders' Association to place certain units of its testing apparatus at Purdue. The members of the various committees of the Master Car Builders' Association came to Purdue to work out their problems on the testing equipment which they had located here. In 1898 the Master Car Builders' Association air-brake test rack was moved from Altoona, Pennsylvania, and located in the testing laboratories at Purdue. At this time the test rack represented the equipment of a fifty-car train, but in the year 1908 the rack was entirely reconstructed and equipment for two locomotives and one hundred cars was installed. By means of this reconstructed test rack, air-brake equipments can be studied under conditions quite similar to those prevailing in actual service.

Purdue University has the reputation among railroad men of seeking out the facts in an unbiased and impartial manner. It has the reputation of having men in charge of experimental and research work who are unbiased in their opinions and who base their conclusions absolutely on the facts developed. We looked into the personnel of the University. We considered the men who would be in charge of the research work, including Dean Potter, Professor Young and others. We looked into their records and were satisfied with them.

Purdue men are surprisingly numerous on the official staffs of the railroads. Some four or five years ago I was vice-chairman of a committee appointed to study the electrification of the steam railroads of the United States. This committee traveled over more than ninety-five per cent of the electrified steam railroad mileage in this country, and throughout our travels we were impressed by the large number of Purdue graduates holding official positions on the railroads we visited, both on the electrified and steam-operated divisions. Many

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of these Purdue men are serving on committees of the American Railway Association, and the high quality of their work is a considerable factor in the building up of Purdue's reputation.

One of the reasons why the American Railway Association placed this research work at Purdue University can, I think, be very well illustrated by my personal experience in deciding to enter Purdue. When I was about to finish high school it was decided that I should attend some engineering school. My father, being a railroad man who had not had the opportunity of a higher education, asked his superior officer on the railroad to recommend the proper engineering school. Without hesitation the answer came, "Purdue; Professor Goss is at Purdue, and I think so much of Professor Goss that I would send my son to Purdue." That is the reason I came to Purdue, and I believe that the incident very well illustrates the close feeling and co-operation which exists between the Purdue University faculty and the railroads.

In concluding, let me repeat that Purdue University was selected as the location for this unbiased investigation because of its many years of co-operation with the American railroads, its reputation in the field of locomotive research, and its reputation of having men in charge of research work who are unbiased and base their results absolutely on the facts. Purdue has been building the foundation of this reputation over a long period of years, and the wonderful way in which it has entered into the air-brake investigation has thoroughly justified the confidence of the American Railway Association.

WHAT RESEARCH HAS DONE FOR AGRICULTURE

By G. I. Christie, Director of the Agricultural Experiment Station, Purdue University.

This Conference of Industrial Leaders, at Purdue University, should have a far-reaching effect upon industrial and agricultural research in Indiana. It means much at this time for the leaders of industry to recognize the work of this institution. The statements of the speakers indicate in a forceful way that Purdue has rendered a great service and is in a position to do much more for the people of the state.

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The Agricultural Experiment Station of Purdue University was established under the provisions of the Hatch Act in 1887. At that time it was found that the individual farmer was unable to conduct research because of the lack of funds, of equipment, and of training. It was necessary for the Federal Government and the state to finance this enterprise so that the farmers might have help.

In the early days when the pioneers came to Indiana they avoided the prairies because they thought them unfitted for crops. Today these lands are recognized as the best and most profitable in the state. The cast iron plow was thought to poison the soil, and farmers continued to use the wooden plow. When in any section crop production was lowered, when diseases were found among the crops, and when animal and insect pests multiplied, many people believed that the only way to meet the situation was to abandon the section and move to new territory. This practice was followed over a long period of years, with the result that farmers moved from the eastern states into the west. One caustic writer has referred to the early crop rotation in Indiana as follows: "First year, corn; second year, corn and weeds; third year, weeds and corn; fourth year, weeds."

The Agricultural Experiment Station has played an active and important part in bringing about needed and worthwhile changes in agricultural practices. The average yield of corn has steadily increased, and the wheat crop, which had reached a low, unprofitable point, is now gradually coming back. Legumes are being grown on a larger acreage and are helping farmers to rebuild the soil and to meet the needs of livestock.

In northern Indiana there are large areas of muck soil. This soil in its original state, though it appeared to be fertile, developed, when planted to corn, a stalk only a few feet high with a small nubbin which was of little value. A study of the problem at our Indiana Station showed that much of this soil lacked potash. An application to the muck areas of about 200 pounds of muriate of potash per acre has overcome the deficiency, with the result that they produce profitable crops. Today they are used for truck crops, mint, and other crops, and rank among the most valuable agricultural areas in the whole state.

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In co-operation with the U. S. Department of Agriculture the Agricultural Experiment Station is making a study of corn diseases. This study has revealed the fact that some soils are giving poor returns in the corn crop because of the presence of free aluminum-iron compounds which are carried into the corn plants, settle in the nodes, and thus injure the plants. Experiments have shown that the addition of potash to the soils fixes these injurious elements in the soil and prevents in a large measure the injury to the corn plant.

The second step of this important investigation has been the development of a test which shows the presence or absence of potash in the soil. Doctor Hoffer, the leader of the project in our station, has developed a test which is simple and effective. Growing corn plants are sliced with a knife and treated with a few drops of a special chemical. The resulting color indicates the presence or absence of potash in the soil. This test is being used in a widespread way in a soil survey which is now being promoted throughout the central west and the southern states.

Mr. Ross has mentioned the progress in the methods of handling the flax crops in the plant of Mr. Ford. I can agree that this problem is of interest to Indiana and should perhaps receive more attention from our farmers.

Flax was formerly grown in Indiana in large quantities. After a few years, however, the crop failed, and farmers stated that it was injurious to the soil and removed too much fertility. The growing of flax has therefore moved on from Indiana through Illinois, Minnesota, and the Dakotas, and into Canada. Experiments with this crop, conducted by Doctor Balley, who was formerly with the Purdue Station, have proved that the trouble with the flax crop was not wholly the exhaustion of the soil. He has found the flax wilt, a disease which has attacked and reduced the crop to an unprofitable point. Through the experiments, Doctor Balley has produced a variety of flax that is wilt-resistant. The flax crop is now being grown again in territory which had been abandoned, and is giving excellent results. Following the same plan, we believe it entirely feasible to grow the flax crop in Indiana when it is needed.

Mr. Ross has also made the point that Indiana agriculture must result in more than the production of food. It is a fact

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that our farms have been used for the most part in the production of food crops and in the production of livestock for meat. It is also true that there are only so many mouths to be fed and that there is a limit to the demand for food supplies. Therefore I agree that such agricultural products as flax, wool, and others, which might be used in a larger way in industry, offer additional opportunities for our farmers. Investigational work which will aid along these lines should bring great returns to both agriculture and industry.

Indiana is now conducting important development campaigns for the promotion of larger cities and more industries. It is proposed to make Indianapolis a city of a million people. We know well of the great growth of Gary, East Chicago, Hammond, South Bend, Fort Wayne, Muncie, Richmond, Laporte, Evansville, Terre Haute, and other cities. There is every evidence that the industries are well founded and that rapid growth will be made. We are now conducting a special investigation at our station in the hope that we may determine the necessary agricultural adjustments which should take place in northern Indiana in the next twenty-five years. This study shows that with the coming of the larger urban centers the farmers will have new problems as well as greater opportunities. Industrial leaders recognize that the success of the cities depends upon an adequate, available food supply at a reasonable cost. It is unwise to develop the city at the expense of agriculture. The development of these two must go hand in hand. Provision must be made to give to the young men and women on the farms a fair return for their services, so that they may enjoy the good things of life in the country. It is impossible to operate the farms if our best people are encouraged to take work in the city.

It is evident, too, that the situation will be better handled if the people now on the farms, who understand agriculture, who enjoy that vocation, and who are rural-minded, are retained on the land, rather than have them move to the urban centers and then attempt to conduct a back-to-the-farm movement.

Our industries will do well at this time to join with our agricultural organizations and institutions in a study of the big agricultural problems and to give every possible help to the people on the land.

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THE STATE AND INDUSTRIAL RESEARCH

By Ed Jackson, Governor of Indiana.

I regard this as one of the most important meetings, if not the most important, that I have ever had the opportunity of attending, in my experience, in the State of Indiana. I came here at the invitation of Mr. Ross. A few days ago I had the very great pleasure of being most graciously and pleasurably entertained at the home of Mr. Ross. While I was there he presented to me a picture he was visualizing—a picture of Purdue fifty years hence. Because of his telling me of this wonderful vision that he has of a great research laboratory in connection with Purdue University, which seemed to me not only an inspiring vision but one that was entirely sane and practicable, I was very anxious to have the opportunity of hearing him present this picture to the men and women who are here tonight and who have taken part with such interest. I am sure that you have been very greatly instructed and pleased by the speeches that have been made. This great research laboratory, if established at Purdue University, will play a wonderful part in bringing the State of Indiana to the forefront in this country, agriculturally and industrially.

Some one must lead the way. The great mass of people must be led, and they are willing to be led by those who have the vision and the courage. We have watched the marvelous development of Indiana within the past twenty years. Take, for instance, the new plants of the United States Steel Corporation and the other industries in the cities of Gary, Indiana Harbor and other cities in the northwestern part of our state. I am sure the great mass of the people never thought that the sandy areas upon which those cities are located would ever amount to anything or be of any value to our commonwealth, or that one day there would be tremendous mills and large cities on the shores of Lake Michigan. But men with vision and the courage to pioneer have founded there a great center of population and have added much to the wealth of our state.

Mr. Lilly, here, knows that when his company started the building of their plant near Greenfield, which most of you have seen at least from a distance, the great mass of people

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wondered why he was willing to put his money into it; but we see what the plant has developed into today and what has been given to the world because of faith, courage and ability to carry out visions. We all know that when the name of "Lilly" appears upon a product, that is all the guarantee the civilized world cares to have back of that product.

Now, I have been greatly interested in the statements of these men who have spoken of the marvelous contributions which research has made to our country's progress. I never thought, when I passed through the stone quarry district near Bedford in southern Indiana, of the waste in that stone. I had not even heard that sixty-five per cent of the finished cut stone produced in the United States is produced in these two counties of southern Indiana. Our attention has been called to the great saving that research could effect by the conservation of this product. When we stop to think of how waste can be eliminated in the stone industry and what that conservation of stone would mean to the State of Indiana if this stone were applied to service, we realize that the production would be of a magnitude that has never even been thought of. It is indeed worth the time and talent and money necessary, to correct the waste existing in such industries as the stone and coal industries in Indiana by means of a research laboratory here. A laboratory can be established that will make it possible to use, to the fullest extent, all of Indiana's resources.

I was indeed challenged by the thought presented by one of the speakers tonight that we waste the greater part of the coal that is mined, securing only a very small portion of the heat and energy that should be secured from this coal, instead of conserving it for our generation and for future generations. Think what a saving if we were able to apply to the industries of our state all the heat and energy that can be produced from the coal that comes from the bosom of the friendly earth!

I have likewise been challenged by the thought that was presented to me a few days ago by Mr. Ross that there must be complete co-operation between industry and agriculture. What a marvelous outlook would be afforded our great State of Indiana by a research laboratory! It would aid the farmer to diversify the products of our state by raising not only food

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products but products which could be absorbed by industry. Corn sugar, for instance, could be used to increase greatly the value the farmer gets from the corn that is raised in Indiana. Giving the farmer the benefit of the investigations and experiments carried on in the laboratory would enable him to make of farming a thing of interest and profit to himself and a thing of great benefit to the State of Indiana.

So you could carry out the idea in industry and in agriculture, and indeed in all lines of activity; for the things I have mentioned are only a part of what a great research laboratory here at this wonderful school of Purdue might be expected to accomplish.

I am glad Mr. Ross invited me to be here with you tonight and to hear what he has to say, and what others have to say, and to ascertain the thought of leaders in industry, in agriculture and in university work, who are doing their part in their day and generation.

These men of vision who have spoken here tonight have pictured the State of Indiana that we shall see fifty years from now as the most densely populated of the forty-eight states of the Union, with industries, many of which are now not even thought of, extending from border to border. With the impetus furnished by the research work of a great laboratory here at Purdue University, there will be established an even balance between agriculture and industry, and an era of prosperity such as we can scarcely conceive. And then, of course, we shall always consider high-class citizens as being one of the most important finished products of this University—men filled with the idea of usefulness, co-operating fully in the development of every great project for the betterment of our generation and the generations to come.

Finally, I want you to consider with me just a moment the great extent of the natural resources of Indiana and the conservation of these resources in such a way that we of this generation shall secure the greatest benefit from them, and so that we can hand them on to future generations. Our natural resources not only stimulate industrial development throughout the state, but also present a splendid opportunity for our trained and equipped young people to spend their active years in pursuits remunerative to themselves and of great usefulness to others.

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PURDUE UNIVERSITY AND ITS SERVICE TO INDIANA

By Edward C. Elliott, President, Purdue University.

Purdue University has the reputation within and without the State of Indiana of being a practical institution. Yet, we who belong to the institution have a sincere pride in claiming that Purdue University is also an idealistic enterprise. This meeting tonight is evidence of an onward and upward striving. We are here because a leader among us has sought to point the way to a realization of a dream of better things for our students and for the great state of which we are a part. The roots of his utilitarian philosophy are always watered by the springs of his unselfish, far-seeing idealism.

Purdue University does not consider, ladies and gentlemen, that it will ever have served its larger purpose until the vast majority of the people of Indiana, of whatever class or occupation, come to feel freely and to know certainly that this institution—their University—is a worthy agency, ever at their disposal for aiding them to secure their material satisfactions and to attain the higher ideals of their lives. The University is guided in its development by the principle that education prepares for productive work, and that such work must in turn re-create education. It is, I believe, fair for me to assume that this is also the philosophy of this group of representative leaders of the industrial interests of Indiana.

The record shows that each year more than three thousand ambitious young men and women are taught as students on this campus. But the story of our teaching service is not completely told until you know that, through the experimental stations and extension work in agriculture and engineering, the teachers and scientific workers of the University reach, directly and personally, approximately 500,000 Indiana citizens every twelve months. The time-honored academic grove has become a veritable forest reaching to every border of the state.

Dean Potter has just given an illuminating account of the activities of our several engineering schools. In these schools today are being trained the young men who, in the years that lie immediately ahead are destined to serve and to lead in the wealth-making industries of Indiana. To the limit of facilities and opportunities, those composing the engineering staffs

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of the University are constantly seeking to distribute directly to existing industrial establishments the best fruit of scientific knowledge. Thus Purdue teaches, and at the same time reaches for the things that make for the betterment of men's work and consequently the betterment of men's citizenship.

The word "research" has been used many times tonight. Striking and convincing illustrations have been offered in proof of the real values that may be derived from organized scientific efforts to find new answers to new and old problems. In the last analysis "research" may be regarded as a fixed determination to become free from the bondage of waste—waste of material, waste of power, waste of men.

A few months ago the United States Chamber of Commerce reported that at the present time nearly $35,000,000 is spent annually by American manufacturers in research work and that probably $500,000,000 is saved and produced annually in consequence of such research. In this day of speed and competition, no productive enterprise can long protect itself and its profits behind the walls of established practice or old experience. The price of twentieth century progress must ever be paid with the coin of new truth. The processes of production, and the processes of consumption as well, must be studied with a view of gaining precise knowledge. What a convincing example was that offered by Mr. Brightly a few moments ago in his presentation of the evolution of the Indiana Stone Industry and of its present-day problems! Intelligent research is a form of insurance against waste and a guarantee of the wise conservation of our resources.

There is one aspect of the worth of the kind of research we are here considering to which some passing reference is timely. As Americans and as Hoosiers we have heard for some years and undoubtedly shall continue to hear for some years the cry, "Taxes must be lowered!" In so far as this represents a need for the reasonable limitation of the number and extent of governmental undertakings and a need for an effective economy in all public expenditures, this demand has justification. Yet I do not think I am in the role of a false prophet when I express the judgment that no appreciable, permanent reduction in our public expenditures in Indiana will be accomplished as long as we adhere to our present

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standards of living, of comfort and of convenience. Habituated to these standards, our people will not allow them to be distinctly lowered. It is my conviction that the one best way leading toward lowered taxes is along the path of an increase in our productive abilities. If, through rigorous and competent investigation, ways and means can be found to eliminate recognized wastes in our industries and in our agriculture, and if through such means we can finally bring about the establishment of new industrial processes and indeed entirely new industries, then the foundations for our economic security and progress will be broadened and deepened sufficiently for us to retain the benefits received from tax-supported communal undertakings. When appreciable additions are made to the material wealth of the State, then more and more of our people are given the chance to have a larger share of the benefits of the best civilization that the world has ever seen.

It is not my intention, Governor Jackson, to divert the attention of this meeting to the very complicated moot question of tax reduction. However, the inevitable relationship between scientific research, industrial prosperity and public taxes is one not to be overlooked by those charged with the responsibilities of civic leadership.

We must believe those who are entitled to speak upon the question, when they say that Indiana is in the beginning of a new era of industrial development. Through your interest and co-operation new avenues of industrial usefulness can be opened for the University. While Director Christie was speaking tonight concerning the tremendously important results of the work of the Agricultural Experiment Station, I was reminded that the work of this station is carried on in the closest connection with the agricultural leaders of the State. By the provisions of legislation enacted in 1909, the leading agricultural organizations of the State—the State Livestock Association, the Indiana Farm Bureau Federation, the State Poultry Association, the State Dairy Association, the State Corn Growers' Association, and the Indiana Horticultural Society—each appoint one member of an advisory committee for the Agricultural Experiment Station. This committee meets at least once a year for the purpose of dis-

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cussing with the officers and workers of the station the program of work which should be carried out. It may be said without reservation that the influence of the station has been greatly magnified by the wise counsel of those who see the agricultural problem from an intensely practical point of view.

Is it not possible for the industrial interests of the state to effect scientific co-operation with the University similar to that already effected by the agricultural interests? The University has been able to serve agriculture because agriculture brought its problems to the University. The high motive which actuated Mr. Ross in asking you to be his guests tonight would receive its most effective response were steps to be taken now for the formation of an advisory industrial council which might serve as the connecting link between the research laboratories of the University and the problems of our Indiana industries. Such an organization operating under the sanction of law would give an opportunity for a variety of constructive co-operation which would by its very nature increase our wisdom and our wealth—both of which are essential elements in that prosperity which will endure.

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INTERPRETATION OF THE SPIRIT OF THE CONFERENCE

By D. E. Ross.

We have attending this conference persons from within and without the State who are accomplishing many interesting things, and who certainly can appreciate the significance of the truths which have been stated here tonight.

It is my personal belief that this meeting has been a very successful one. It would be wise to get the representatives of the industries to appoint a committee that would go through the great research laboratories and report back to this body before the Legislature meets, in order that an Advisory Council for an Engineering Research Laboratory, similar to the one which we now have for the Agricultural Experiment Station, could legally function. With this end in view I should like to suggest that we get into communication with the Indiana Manufacturers' Association and the Indiana State Chamber of Commerce, so as to promote the nomination of the proper persons to constitute this committee of investigation. If there is no objection, we will take this as the method of procedure.

NOTE: Committees have been appointed by the State Chamber of Commerce and by the Indiana Manufacturers' Association to carry out Mr. Ross' suggestions.

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PUBLICATIONS OF THE ENGINEERING EXTENSION DEPARTMENT

Circulars

CIRCULAR No. 1. Care of Roads During the Spring Break-up, by Ben H. Petty, 1923.

CIRCULAR No. 2. Watthour Meter Accuracy on Light Low Power Factor Loads, by D. D. Ewing and D. T. Canfield, 1924.

CIRCULAR No. 3. Hints on Automobile Maintenance, by H. A. Huebotter, 1924.

CIRCULAR No. 4. Operation of Three Phase Induction Motors Under Abnormal Supply Conditions, by D. D. Ewing and C. F. Bowman, 1924.

CIRCULAR No. 5. Publications of Engineering Experiment Station and Engineering Extension Service, 1924.

CIRCULAR No. 6. Why Our Road Maintenance Costs are Increased so Rapidly, by Ben H. Petty, 1924.

CIRCULAR No. 7. Road Law Procedure in the State of Indiana, by E. L. Arnold, 1925.

CIRCULAR No. 8. Laws Governing Municipal Improvements, by W. S. Moore, 1926.

Bulletins

BULLETIN No. 1. Fundamentals of Construction and Maintenance of Secondary Highways, by C. C. Albright. 1922.

BULLETIN No. 2. House Construction that Reduces Heating Costs, by James D. Hoffman, 1923.

BULLETIN No. 3. Pictorial Description of Engineering Activities, Purdue University, 1923.

BULLETIN No. 4. Electric House Pumping Systems, by G. C. Blalock and D. D. Ewing, 1923.

BULLETIN No. 5. Proceedings of the Tenth Annual Road School, by Ben H. Petty, 1924.

BULLETIN No. 6. Proceedings of the Second Annual Conference of Indiana Foundrymen, by J. P. Walsted, 1924.

BULLETIN No. 7. Thawing Water Pipes with Electric Current, by D. D. Ewing and C. F. Bowman, 1924.

BULLETIN No. 8. Connection Checks for Polyphase Watthour Meters, by D. T. Canfield, 1924.

BULLETIN No. 9. Reconstruction of Old Gravel Roads, by C. C. Albright and R. E. Mills, 1925.

BULLETIN No. 10. Proceedings of Eleventh Annual Road School, by Ben H. Petty, 1924.

BULLETIN No. 11. A City Planning Primer, by G. E. Lommel and F. G. Bates, 1925.

BULLETIN No. 12. Care of Farm House Telephone, by R. V. Achatz, 1925.

BULLETIN No. 13. Comparative Accuracy of Three-Phase Four-Wire Metering Methods, by D. T. Canfield, 1925.

BULLETIN No. 14. Proceedings of Twelfth Annual Road School, by Ben H. Petty, 1926.

BULLETIN No. 15. Proceedings of Industrial Conference, 1926.

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3. **Engineering Extension**
   The Engineering Extension Department is carrying the benefits of the University to the citizens of the State by means of extension classes, conferences, short courses and special services of distinct value to the industries, utilities and public works of Indiana. Over 17,000 people were directly reached by this department from July, 1925, to June, 1926. Fifteen bulletins and eight circulars have been published.

Inquiries concerning Courses of Instruction in Engineering, the Experiment Station, the Engineering Extension Department or Publications may be addressed to

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